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VOLUME VI **10** 1951

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A Northrop F-89 "Scorpion" twin-engined all-weather jet fighter firing off its five-inch rockets. In addition to its standard armament of six 20-mm cannon, the F-89 can carry up to sixteen of these rockets.

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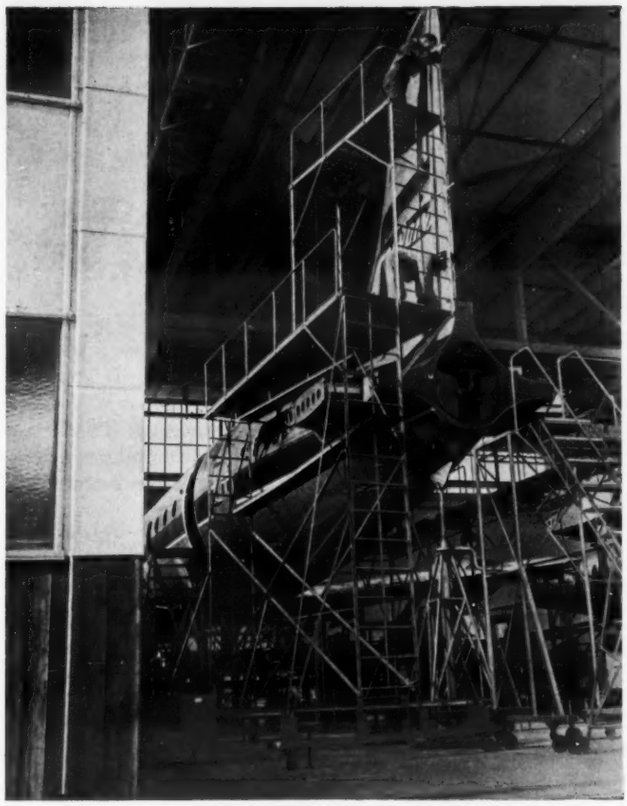

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UNITED AIRGRAM

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WASP ENGINES TO POWER CANADIAN KING BEAVER — The Pratt & Whitney R-1340 Wasp has been selected for the King Beaver, newer and larger version of the Beaver, bush aircraft of de Havilland Aircraft of Canada, Ltd. With this engine the 58-foot span monoplane will easily carry over a ton of cargo or 14 passengers — about double the capacity of the original model. The King Beaver, recently selected as a liaison aircraft by the U.S. Air Force, will be built at the Toronto plant of de Havilland.

Meanwhile, Canadian Pratt & Whitney Aircraft Co., Ltd. of Canada, will tool up a new plant for the manufacture of R-1340 Wasp engines at Longueuil, Quebec.

This Canadian subsidiary of United Aircraft Corporation has not been producing engines but has been overhauling Pratt & Whitney engines since its founding in 1929. During World War II the company manufactured Hamilton Standard-designed propellers.

KOREAN AIRLIFT HIGHER IN DAILY AIR MILES THAN BERLIN LIFT — The trans-Pacific airlift in support of the Korean campaign has been bigger than the Berlin airlift of 1948-49 in terms of daily miles flown, recent figures show.

From the outset, Pratt & Whitney engines have powered almost 100 per cent of the airplanes of the Korean lift, just as they did in Germany. Figures show that the Military Air Transport Service aircraft have been moving 5,000 troops and 1700 tons of cargo monthly from the West Coast of the U.S. to the Orient. Sick and wounded men have been flown back to the U.S. hospitals on return trips.

Workhorses of this giant lift have been four-engine Douglas C-54 Skymasters, equipped with Pratt & Whitney R-2000 Twin Wasps and Hamilton Standard propellers, and Boeing C-97 Stratofreighters, powered by R-4360 Wasp Majors using Hamilton Standard propellers. Outstanding performance of engines and propellers has contributed greatly to the success of this phenomenal operation.

FIRST DOUGLAS DC-6B CROSSES ATLANTIC TO ENTER SWISSAIR SERVICE —Early last July the first DC-6B, bigger version of the DC-6, was ferried overseas to Zurich, Switzerland to be studied by personnel of Swissair. A second DC-6B was delivered shortly afterwards and a third will be completed in mid-1952. DC-6B service by Swissair between New York and Zurich began August 19.

Like the earlier DC-6, also designed by Douglas Aircraft, the DC-6B is powered by four Pratt & Whitney R-2800 Double Wasp Engines. It is equipped with Hamilton Standard propellers. About 200 DC-6s are in service around the world, and more than 100 DC-6Bs are currently on order.

SIKORSKY S-51s EVACUATE 140 FLOOD VICTIMS IN ARGENTINA -- Sikorsky S-51 helicopters were in the news again recently when they were used to rescue 140 people trapped by a flood of the raging Parana River, in the Santa Fe Province, north of Buenos Aires.

Two S-51 helicopters were flown to the distress area and removed the 140 flood victims despite very unfavorable weather conditions.

Fifteen helicopters manufactured by Sikorsky Aircraft in 1947 and 1948 were delivered to Argentina on the order of the Ministry of Agriculture of the Argentine Government.

IGOR SIKORSKY AWARDED THE GUGGENHEIM MEDAL FOR 1951 -- The Daniel Guggenheim Medal and certificate for 1951 for notable achievement in the advancement of aeronautics has been awarded to Igor Sikorsky, Engineering Menager of the Sikorsky Aircraft Division, United Aircraft Corporation, Bridgeport, Connecticut.

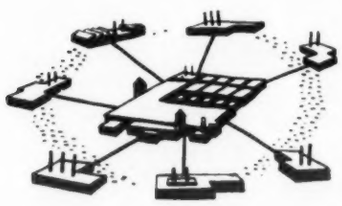
The Medal Board of Award said Sikorsky was selected for his "lifetime of outstanding contributions to aeronautics, including pioneering with multi-engined airplanes, flying boats, amphibians and helicopters."

HAMILTON STANDARD DEVICE CONTROLS FUEL FLOW IN JET ENGINES -- A device described as the most sensitive yet created for controlling the fuel flow into big jet engines was announced recently by the Hamilton Standard Division. The fuel control has already passed endurance tests on Pratt & Whitney Aircraft's big J-57 engine.

The control combines an electronic "brain" with hydro-mechanical "brawn." It not only relieves the pilot of many specialized duties, but accurately governs the speed of the turbine wheel to a close tolerance. The electronic unit senses engine speed and temperatures of air entering the engine and leaving the tailpipe. Any tendency by the engine to exceed its design speed and temperature is controlled by signals to the hydraulic unit to slow fuel flow into the combustion chamber.

The hydraulic unit also measures air pressure into the engine compressor section and establishes a limit to the fuel flow at a level needed to maintain operation during landings and other operations not requiring maximum power. The electronic unit is built in an airtight magnesium casting. An important safety feature is the fact that there are duplicate vacuum tubes to take over for any tube that fails.

UNITED AIRCRAFT SUBCONTRACTING REACHES HUGE PROPORTIONS -- Pratt & Whitney Aircraft since its founding in 1925 has followed a basic policy of subcontracting at least 50 per cent of the building of its engines. From an original list of 200, it now has a total of 5,285 subcontractors. Ninety per cent are classed as small businesses with less than 500 employees each.



In 1951 the engine building division of United Aircraft alone will pay out $250 million to subcontractors and suppliers, and about the same percentage of the contract dollar will be paid out by the other three divisions to outside firms. Altogether, the four divisions have more than 10,000 subcontractors and suppliers in nearly all states of the Union -- with about half in New England.

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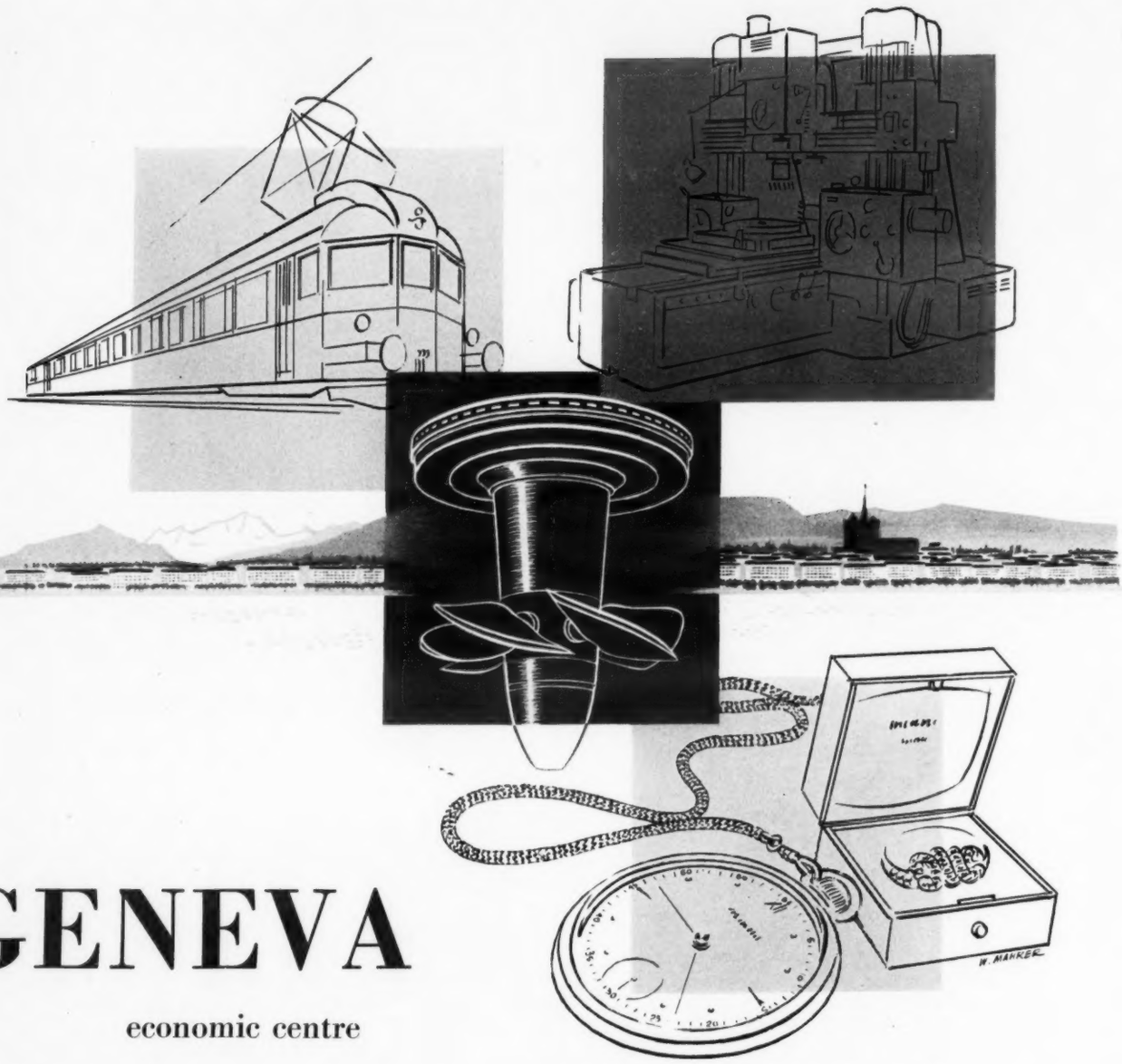

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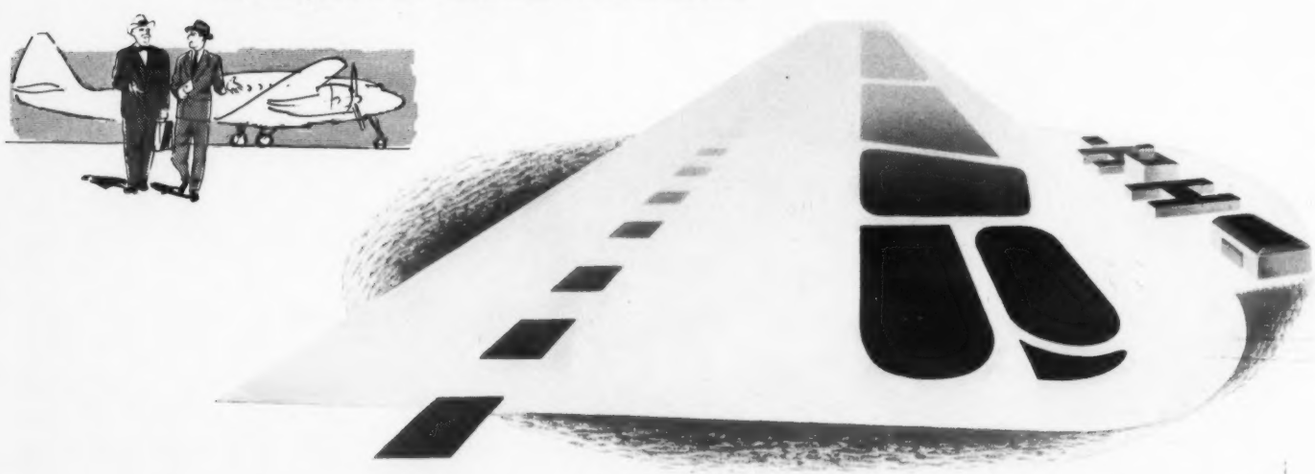

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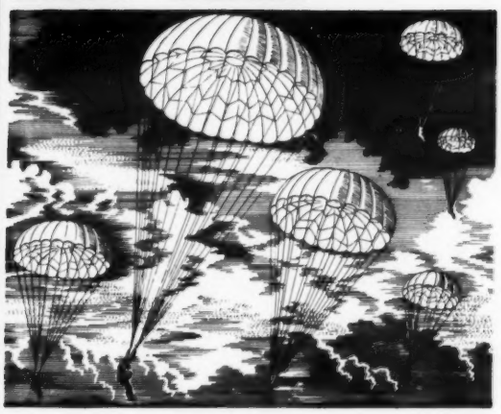

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Madrid Finds a New Suitor

(The American Spanish Talks)

A bare twenty years ago Spain was a highly esteemed member of the League of Nations, and her speeches at the Geneva Disarmament Conference carried considerable weight. At that time the head of the Spanish delegation wrote in Interavia [1]:—

"Spain has a richness in the air above her... which attracts and obliges to pass through her country all the aerial services connecting Europe with West Africa and the South American countries. In these conditions and for her own interest it is not necessary for Spain to conclude either treaties, conventions or rights, as no one can offer her by according free passage of the air, equivalent advantages to those that she can offer the majority of other nations. It is even less necessary for Spain to accept any international regulations under which she would have to freely concede all the benefits to which she has a right by virtue of her exceptional geographical and climatic position, without for this obtaining the slightest compensation..."

Much water has flown under the bridge since these words were written. The Civil War left Spain with heavy mortgages; German rearmament, the Abyssinian War, the Steel Pact, the Axis alliance, all drew international attention away from Spain, until the country more or less sank into oblivion during World War II.

It is therefore all the more astonishing to find Franco, in the summer of 1951, using almost the same words as the Spanish disarmament delegate in 1933. Fundamentally Franco uses the same reasoning to explain Spain's indifference to the question of joining the Atlantic Pact and justify her putting a high price on any naval or air bases she may cede to the USA.

General Francisco Franco Bahamonde, head of the Spanish Government, remarked on the subject of the American-Spanish talks on bases: "If the international situation demands the active cooperation of Spain, then it is essential that a contribution be made towards the rapid recovery of her economy and military power."

Perhaps the most astonishing feature of all, however, is that these arguments which at first glance appear to be so presumptuous are largely founded on fact.

South America, Pyrenees and flight distances

The Spaniard is doubtless sufficient of a realist to recognize that the Spanish nation's only endowment at the present time is the favourable geographical position of the Iberian peninsula and its links with the Spanish-speaking countries of South America. Spain's present-day industrial, transport and military organization, despite valiant efforts and undeniable progress, is still not such in itself as to make the country into a desirable ally.

This is not the place to speak of the much-discussed stagnation of Spanish industry, which is attributed by Spanish industrialists themselves to a chronic lack of capital. We shall not go into the deplorable condition of the Spanish railways, which run for the most part on single tracks and have to make do with aged permanent way and rolling stock. Nor shall we discuss the Spanish Army, which has excellent soldiers (roughly 250,000) ...but no modern equipment or armament; nor yet again the Spanish Navy whose most modern 10,000-ton cruiser was launched in 1935. Our sole interest lies in aviation, its ground organization and the as yet undeveloped possibilities which Spanish territory offers to modern air units.

A glance at the map will illustrate these points more clearly than any words can do. There is no need to reiterate the well-known fact that large sections of Central and South America use the Spanish language, that over 120 million people speak Spanish, think and feel more or less Spanish. However it should also be remembered that Spain can not only play the role of mediator for Latin America, that an American-Spanish *rapprochement* would not only reopen the whole question of Catholic South America, but also that, for example, the national language of the Philippines, despite the latter's breaking away from the Spanish colonial family, has remained Spanish. Central and South America, Europe, North Africa, Pacific... there are Spanish peoples east and west of the Iron Curtain at all the key points of world politics in 1951.

Quite apart from these political considerations it cannot be denied that European Spain with her islands, her long coasts, her thinly-populated plain would appear to be an ideal land for bases. Great Britain

[1] Interavia, International Correspondence on Aviation, No. 21, 1933, "Spain in the World of Aviation."

General E. Gonzalez Gallarza, Spanish Air Minister, retained his office despite the reshuffle of the Spanish Government. His recent visit to the USA where he made detailed inspections of American aircraft works and training bases was the prelude to the present discussions in Madrid.

Vicente Roa Miranda, Director General of Ground Organization.

Rafael Martinez de Pisón, Spain's Director General of Civil Aviation.

and France are good aircraft carriers for the West, but Spain could become an ideal outpost for the USAF. Accessible on land only via the Pyrenees, it would form an almost impregnable air base area, from which Central Europe, the Balkans, Southern Russia, the Near East could be reached within a few hours. Using Spain as an aircraft carrier, it would not even be necessary, in the event of war, to employ long-range bombers or transports, since the lengthy crossing of the Atlantic would be eliminated: distance to Berlin 1120 miles; Athens 1360 miles; Batum 2230 miles; Moscow 2110 miles; Suez Canal 2110 miles; Persia 2910 miles. Spain could become the first stage on the route to India and the Far East. She represents, one might say, one arm of a pincer, with Japan as the other.

The fly in the ointment

These are some of the reasons which have led the American Defense Department to press, after so many years and despite certain misgivings and considerable opposition from American domestic and foreign policy, for a treaty with Spain.

The men in Washington's Pentagon are of course no blind partisans of General Franco or of Spain, and their knowledge is not restricted to such elementary information on Spain. The responsible planners of the three American armed services will scarcely be under any illusion as to the problematical value of the four Spanish naval bases (Cadiz, Carthagena, Mahon and El Ferrol), or the present condition of Spanish Air Force bases (Los Alcazares, Alcala de Henares, Moron de la Frontera, Valenzuela, Palma, Tiliuin/Morocco etc.).

Doubtless it is no secret in Washington that Spain's, ground organization in its present state, would be hard put to it to cope with the tremendous transport requirements of her potential American ally.

Runways suitable for large inter-continental aircraft at present exist only at the Spanish civil airports of *Madrid-Barajas* (10,000 ×295 ft. and 8530×197 ft.), *Seville-San Pablo* (6,400×164 ft., 4,920× 164 ft.) and, with certain limitations, *Barcelona-Muntadas* (4,930×295 ft. and 4,540×197 ft.). San Bonet, Majorca, Spain's fourth largest airport, has no concrete runways (rolled earth, maximum dimensions of airfield 5,120×980 ft.), in spite of the fact that it handles more passenger and goods traffic than the port of Seville. The only ILS installation is at Madrid-Barajas, while Barcelona-Muntadas has barely adequate equipment for bad weather landings (standard beam approach, homing transmitter).

Hope for the future is provided by Seville-San Pablo, which is now being enlarged and which, when it is completed in 1960, will have three concrete runways 9840, 6400 and 5250 ft. long and will take the majority of future inter-continental traffic.

In view of the relatively primitive condition of the ground organization one cannot help admiring the achievements of IBERIA, the Spanish air transport company which, with a hard core of really efficient pilots, handles heavy traffic almost without accidents, takes over a good share of the responsibilites of the defective ground transport system and, as we shall see later, represents a not inconsiderable factor in Spain's military potential.

*

As for the Spanish *Air Force*, its greatest asset—like the Army's—is the energy and the high morale of its men, and its efficient training system. There are several flying training schools with good trainers, some of them of Spanish manufacture. Spanish aero clubs have also been giving thorough training to civil pilots since the war and these now form a valuable reserve for the Air Force. —On the other hand only a fraction of the approximately 900 first-line aircraft is operationally serviceable, which is not surprising, considering that the whole military air fleet dates from before World War II and consists largely of old German and Italian types for which no spares are available today (fighters: Messerschmitt Me 109-F; bombers: Heinkel He 111, Dornier Do 17 etc.; Junkers Ju 52). This is the result of the boycott imposed against Spain by UNO and ICAO a few years ago.

The offers

A great deal of preliminary work had to be done before the American military and economic delegation could sit down at the conference table with their colleagues in Madrid.

It was not until the autumn of 1950 that the United Nations reversed their decision, taken during the first year after the war, that diplomatic relations between the West and Spain should be broken off and that the latter should be excluded from the technical organizations affiliated to UNO (including the International Civil Aviation Organization).

*

Inside America the principal opposition came from the State Department, who regard harmonious relations with the other members of the Atlantic Pact as too valuable to be jeopardized by a *rapprochement* between the USA and Spain. An interesting point is that the old antipathy, where Spain is concerned, between the State Department and the Defense Department was not overcome until former Secretary of State George C. Marshall, a past master at handling people, had taken over the Defense Department. Marshall, an uncompromising critic of any anti-Spain policy based purely on sentiment, had been advocating ever since the autumn of 1948 (press conference of October 9th, 1948) that American-Spanish relations be put on

Madrid-Barajas, Spain's busiest airport. Traffic figures for 1949 (Anuario Aeronautica Español 1951): 12,716 aircraft, 192,481 passengers, 1,180,372 kg freight.

a more normal footing and that UNO's decision on Spain be abrogated. By April 1st, 1949, the Spanish national holiday, the first vague hints of "American bases on Spanish territory" were appearing in the press.

The most persistent opposition, however, —and it has not yet been overcome—came from London and Paris. The attitude of the European Atlantic powers is probably determined not only by dislike of Spain's form of government but also by concern that some of the existing bases in the Mediterranean might be deprived of their value if Spanish naval and air bases became available. They also no doubt argue—perhaps not without reason—that Uncle Sam's generosity might be sensibly reduced if yet another "good little nephew" were drawn into the circle of recipients of arms aid.

*

Disregarding therefore the very mixed press commentaries in various European countries, the Americans have now made Madrid a definite offer. We are of course no more in a position to give details of the programme of the two parties than are the hundreds of reporters at present besieging the Prado and plaguing the life out of General Franco.

On the *question of bases*, we have received the following report from Spain:

"The first commentaries on this subject mentioned the placing at the disposal of the Americans of a number of Spanish bases at present in use by the country's own naval and air forces. This does not seem very likely, particularly if incidents and friction affecting the cordial relations between the two countries are to be avoided. It is more probable that Spain will allocate to the United States certain strategic points for the construction of bases, although U.S. forces may provisionally be permitted to use facilities already in operation.

"Both Spanish and American official circles continue to observe complete silence on what bases the United States would obtain in Spain. Nevertheless a reasonable guess can be made of their location.

"The major flow of international air traffic follows an east-west course on a line from Rome via Palma (Majorca), Barcelona and Madrid to Lisbon. If the USAF is to be given bases at once, presumably the only feasible ones would be Seville and Valencia airports, since both are equipped to handle heavy aircraft and at the same time are sufficiently removed from the most heavily travelled commercial air routes.

"Whether the temporary cession of these two airports is being considered or the immediate construction of special American bases is planned, the problem of air bases is intimately connected with that of naval bases. A possible solution is given in broad outline below:

Combined air and naval bases :

(1) *Northwest Spain (Galicia) :* a naval base to handle sea-borne supplies from America, plus a neighbouring air base as point of liaison.

(2) *South-east Spain (Murcia) :* a combined air and naval base, one of whose tasks would be to maintain liaison with the Spanish Navy and Air Force (training, practice, joint operations).

(3) *Balearic Islands :* a naval base as second-line to Naples, with an air base of secondary importance.

Air Bases :

(1) *South of the Pyrenees :* a strategic air base in the cone formed by the Pyrenees and the commercial air routes crossing Spain. It could be located in the vicinity of Alfamen (south-west of Saragossa), on a vast natural plain which could be converted at relatively small expense into one of the greatest air bases in Europe. (Alfamen has already been used as an airfield, during the Civil War.)

(2) *Central Plateau :* the establishment of an air base elsewhere on the Castilian plateau is very doubtful, since Alfamen base would be in constant touch with Madrid, seat of the Spanish Government and of the American Embassy, through the airport of Madrid-Barajas. The latter's dimensions and climatic conditions are such that military liaison services could function from there without interfering with the civil air services."

Whether our Spanish correspondent is correct in his preliminary survey remains to be seen. The only thing that is certain at the moment is that the American military delegation at present in Madrid is headed by Major General J.W. Spry, Chief of the Atlantic Division of the Military Air Transport Service, and that a good percentage of the other members of the delegation come from the transport branches of the three armed services. To assume from this that the USA is planning only the establishment of "supply bases" and not of strategic operational bases, would be premature. The organization of any system of bases must begin with the question of supplies.

And Spain?

In view of the foregoing it is not difficult to visualize what Spain might ask in return. The country's Army, Navy and Air Force must have modern armament and equipment if they are to afford U.S. forces any effective help. Agriculture, industry and transport need capital and new outlets to start them off on the road to productive activity.

What the Spanish can accomplish when in the possession of modern equipment has been amply proved by the Spanish airline IBERIA. On the company's domestic services nearly all the aircraft are regularly filled to capacity. Traffic figures could be trebled without much difficulty if the necessary flying equipment were available. This applies also to inter-continental routes, on which the Spaniards still have to match their competitors' Douglas DC-6s and Lockheed "Constellations" with old DC-4s. The only reason for the surprisingly high load factor on these services is the high rate of emigration from Spain to South America. With a fleet of, say, eight Douglas DC-6s, ten DC-4s and twenty DC-3s IBERIA could become, thanks to its excellent staff of pilots and its efficient management, the equal of many of the greatest airlines on the Continent of Europe.

What applies to Spanish air transportation is true also of industry, mining and agriculture. Spain, a country which lost its most

Major General J.W. Spry of the Military Air Transport Service, head of the American military delegation (right), arriving at Madrid-Barajas airport.

profitable colonies some 150 years ago, which has largely wasted its substance through internal disorders, could awake to new life and play an important part in the concert of the nations if her industrious, uncomplaining but self-reliant people could count on the unfailing understanding of the Western world. How much the recovery of Spain would cost is not known. Nevertheless it is quite possible that the American negotiators will apply the traditional principle of the New World... and give Spain a chance.

A General Staff Headache: Faster Speeds Demand Better Armament

BY LIEUTENANT-COLONEL PIERRE M. GALLOIS, FRENCH AIR FORCE STAFF, PARIS

Captain James Jabara, victor of fifteen air fights and first U.S.A.F. jet air ace, is reported to have said upon his return from Korea that he would willingly exchange the six .50-cal. machine-guns of his "Sabre" fighter for four 20-mm cannon. With one or two hits from the cannon he could probably get better results than with fifteen hits from his machine-guns. Since the Soviet MiG-15 was armed with a 37-mm cannon plus two 20-mm or 23-mm cannon, it was hardly surprising that the American B-29 "Superfortresses" were easy game for the Russians.

Similar thoughts were expressed by Captain Hinton, another successful American fighter pilot, who said he had to fire 1400 rounds to knock down a MiG. But the Americans were not even doing badly in the circumstances, since they succeeded in shooting down about four enemy aircraft for the loss of one of their own machines. If the U.S.A.F.'s F-86 "Sabre" fighters were equipped with more powerful guns the story would be entirely different.

This raises the old question: should fighter aircraft be equipped with large-calibre guns, notwithstanding the fact that this would lower the rate of fire? The problem is much more complex than that. Until the first jet fighters clashed in the air above Korea, any evaluation of the combat suitability of the new class of fighter had to depend on estimates. Owing to the lack of sufficiently fast target tugs or of target aircraft having a performance comparable with that of modern combat types, even experienced staff officers were poorly qualified to establish a clear estimate of aerial engagements at near-sonic speeds. Furthermore, analysis of the first results of this Chinese-American air war has not proved simple. The "Sabre" and the "MiG-15" resemble each other closely as regards flying performance, although the MiG seems to have a slight speed advantage at great altitudes, whereas the "Sabre" possesses better endurance. On the combat qualities of the opposing pilots, very little information is available. American pilots believe that their opposite numbers are mostly World War II veterans who initially employed conventional air tactics but learned better after a few engagements. The pilots of the U.S. Air Force? They combine the latest experience of World War II with very careful training in the tactics of the new, faster fighters. The most striking difference therefore lies in the armament carried by the two opponents. The MiG-15 fires explosive shells of 37-mm, 20-mm or 23-mm calibre at a rate of 10 to 15 rounds per second per gun. The "Sabre" is armed with six .50-cal. machine guns firing 20 rounds per second each. Now the "Sabre" is an excellent gun platform, whereas the firing precision of the MiG leaves something to be desired. Even though an inferiority of this kind might be decisive at modern combat speeds an overall appreciation is difficult to arrive at: does victory or defeat in air combat depend upon calibre or sighting accuracy?

The lessons taught by the Korean air war are incomplete and conflicting. While the characteristics of engagements between fighter pilots can be accurately evaluated by both opponents, the Chinese-Korean air forces have the unilateral advantage of having gained practical experience also in jet fighter attacks on piston-engined bomber formations with their own defensive armament and fighter protection. Inversely, neither the Eastern nor the Western fighters have so far had an opportunity of testing their effectiveness against light or medium jet bombers, such as the Boeing B-47 "Stratojet" or the Tupolev Tu-10. Granted, combat between jet fighters can provide valuable indications for the interception of light and medium jet bombers, but it is still an open question of what value fighter defences will be against the potentially decisive intervention of the jet bomber in the event of a global war.

Soviet and American jet fighters in Korea are roughly equal to each other. To revert to World War II experience, it may be recalled that at the end of 1944 the ratio of Allied to German air losses was about 1 to 1. When the Messerschmitt Me 262 twin-engined jet fighter came into squadron service at the beginning of 1945, equipped with new 30-mm, R4M aircraft rockets [1] and an EZ 42 automatic gun sight, the ratio is said to have increased to about 7 to 1 in favour of the Luftwaffe. This was the result of a revolutionary engineering development which outmatched the conventional aircraft and armament then built in Britain and the U.S.A. For Britain and the U.S.A. a similar conventional changeover would have been doubly difficult since the mass production of conventional aircraft was then at its peak.

What about today? *Experts in every part of the world are unanimous in their opinion that development of aircraft armament has lagged behind airframe and power plant engineering, even behind the development of radio and electronic equipment.* In the final analysis the fighter aircraft is merely a flying gun and the bomber a means of transporting bombs, the latter seeking protection in its defensive armament or high speed, or both. The aircraft designer and gun manufacturer should long have sat down together to work out the best compatible solution in the development of aircraft armament and the aircraft designed to carry these guns. They have been going separate ways, however, and each has sought individually to produce the best aeroplane or the best cannon. In this fact lies the principal difficulty.

Speed Invalidates Traditional Experience

First of all it should be pointed out that modern aircraft—jet fighters or jet bombers—are less vulnerable to conventional weapons than their predecessors. Developed for flight at speeds approaching the sonic limit, modern combat aircraft offer very small frontal areas. Compare the silhouette of a Boeing B-17 "Flying Fortress" [2], with a gross weight of about 49,500 lb., with that of a Boeing B-47, which has a gross weight of approximately 185,000 lbs. The new Boeing bomber is developed for high speeds at both high and low altitudes; it is of rugged construction, has a thick wing skin and therefore is much less vulnerable to gunfire. In addition, numerous features have been incorporated to make its airworthiness as immune as possible from localized damage.

Technicians have so far contented themselves with measuring the effect of modern projectiles by using old equipment of World War II vintage ("Spitfire," "Flying Fortress," "Mustang," "Marauder"). The speed of these aircraft barely reached 400 m.p.h. The results indicated, as described by Ing. O.P. Fuchs in an earlier issue of this journal [3], that a piston-engined bomber of 1945 could

[1] Supersonic rockets of 55-mm calibre of a launching weight of 7.7 lbs. and a weight at the target of 6.0 lbs., with a rate of fire of up to ten rockets per second.

[2] Which had a frontal area of about 323 sq.ft.

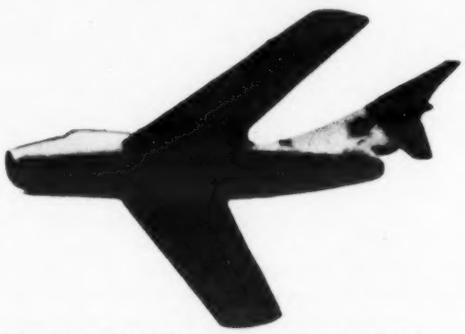
[3] Cf. "Interavia, Review of World Aviation," No. 1, 1948, pp. 38-41.

North American F-86A "Sabre" has six .50-cal. machine-guns.

be destroyed or put out of action by twenty hits with 20-mm explosive shells (each with an explosive charge of 0.9 oz.) or by seven hits with 30-mm explosive shells (each with an explosive charge of 3.2 oz.) or by one hit with a 55 or 60-mm shell (explosive charge of 14.1 oz.). Aircraft of yesterday are comparable neither in design, structure, covering nor frontal area with modern types, of which only small quantities are available at the present time but which will form the standard equipment of the world's air forces tomorrow. Five years ago a single 30-mm shell was enough to finish off a "Spitfire." Is this true also for the U.S.A.'s "Sabre," Britain's Hawker "P. 1067" or France's Dassault "Mystère"?

Both in a fighter attack on a bomber (especially on a bomber with tail armament) and in air combat between fighters (in which the maximum permissible centrifugal acceleration in turning away plays an important rôle), the increasing speeds have also resulted in considerably greater firing distances. With increasing firing distances, the total dispersion of fire has augmented correspondingly (for a 20-mm projectile it amounts to about 15 yards at a firing distance of 1000 yds.) and the hitting probability diminished. Hence, muzzle velocity of ammunition fired on a target flying in the same direction must be increased to improve firing accuracy, to reduce projectile travelling time and to raise projectile energy at the target. On this point, engineer and air gunner seem to represent opposing interests. Weight and space requirements of aircraft guns become virtually prohibitive if great muzzle velocity is to be achieved. Examination of the latest German World War II aircraft gun shows that an increase in muzzle velocity by 40% can result in a weight increase by as much as 80%. Cannon with a weight of 130 lbs. or 180 lbs. each are about the maximum which can be housed in the fuselage of fighter aircraft. If their weight is doubled, their number must be halved. Since an increase in muzzle velocity reduces rate of fire and since rate of fire is the most important single characteristic of modern cannon, an excessive boost in muzzle velocity automatically is out of the question.

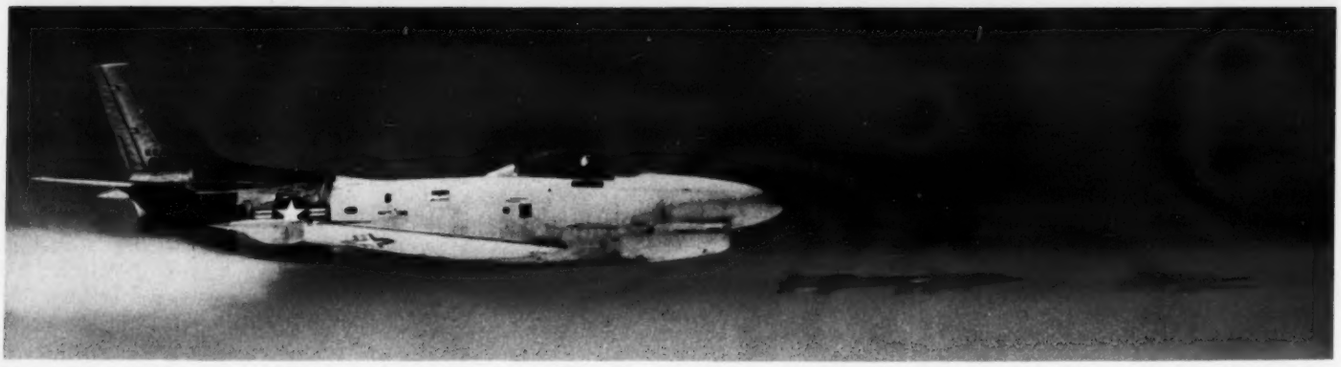
Assuming a rate of fire of about 15 rounds per second for each of a fighter's cannon, a bomber flying at a speed of 660 feet per second would fly about 40 feet between two rounds fired from one gun, *i.e.*, somewhat less than its own fuselage length. If a fighter carries four cannon, the advance of the bomber is only about ten feet between rounds. If lateral fire—hardly practicable today—is considered, even this advance is substantial. A modern fighter's prospects



Mikoyan-Gurevich MiG-15 totes one 37-mm and two 20-mm or 23-mm cannon.

of shooting down even an old bomber (1945 vintage, 250 m.p.h., four .50-cal. machine guns) are therefore poor or non-existent if the enemy flies in close formation and maintains "hedgehog-type" fire from its defensive guns. The fighter's four 20-mm cannon, his attack from behind and his firing distance of between 980 yds. and 330 yds. (*i.e.*, within a space of just over

The Messerschmitt Me 262 Series A-2 twin-jet two-seater night fighter version of the well-known German jet interceptor had four 30-mm MK 108 cannon plus R 4 M air-to-air rockets. Two jettisonable tanks under the fuselage increased the night fighter's endurance. Radar antennae are mounted on the fuselage nose.



Guns and rockets: the North American F-86D, latest version of the "Sabre" fighter, can fire up to 24 "Mighty Mouse" three-inch rockets against aerial and ground targets.

two seconds at speed of flight) will not alter this fact.

Calibre Increase is a Blind Alley

Is there a way out of the impasse? Weight and space requirements increase sharply if higher muzzle velocities are to be achieved. In view of this fact, it is not possible to increase the number of guns, although this would be the only way to offset a high degree of dispersion and low rate of fire. What should the fighter pilot do? He asks the gun designer for a cannon of greater calibre. For tactical reasons the firing distance cannot be reduced; if anything it has a tendency to grow. With the shortening of the effective combat period, the hitting probability in turn decreases. Weight and space requirements for the cannon prohibit, as emphasized, an increase in the number of weapons. The gunner therefore quite logically demands a weapon permitting him to kill his enemy with a single hit. Calculations now have shown that an old bomber of good stability and good carrying capacity —and therefore much more flexible regarding the number of its defensive guns—will succumb to nothing less than a calibre of 55 to 60 mm. But in combat against advanced-type jet bombers of even more robust construction, in other words, aircraft which must be attacked from even greater firing distances, one is faced by two alternatives: greater number of hits or even heavier calibre.

Cannon of 60-mm calibre weigh no less than 880 lbs. With increasing calibre the rate of fire diminishes: only five or six rounds per second instead of 15 to 20. To augment the weight of fire by increasing the number of heavy guns is not possible owing to equipment weight and space limitations. Can the problem be solved by a further increase in calibre? The technician evidently finds himself in a blind alley...

This is the problem facing the General Staffs. Traditional air war tactics are clearly out of date. There is a tendency to seek consolation in the fact that even modern aircraft have very vulnerable spots. There are, for example, the pressurized cockpit, a critical, vital element; greatly enlarged fuel tanks of jet aircraft; fragile parts such as air intakes, radio equipment and bomb-sights. This is poor consolation, however.

The first series of the Gloster "Meteor" twin-jet fighter, which the R.A.F. used against the German V-1 "buzz bombs" in the autumn of 1944, were already armed with four 20-mm cannon.

For strikes against shipping the North American B-25H "Mitchell" twin-engined light bomber was armed with a big 75-mm cannon and eight .50-cal. forward-firing machine-guns in the nose. Movable .50-cal. twin machine-guns were mounted in dorsal and tail positions.

Experience gathered so far has shown that *there is only one answer: radically new types of armament must be adopted, paralleling the advance of aircraft speeds into the sonic range, which has produced revolutionary changes in aircraft engineering.*

For combat between fighters, probably also between fighters and fighter-bombers or light bombers, only one stop-gap solution seems to be possible at the moment: a slight increase in calibre and number of guns. If the calibre is raised from 20 mm to 30 mm and if the number of cannon is brought from four to six, a total fire power of one hundred rounds per second might be achieved. Guns and ammunition will then weigh about 3,300 lbs, or about 20 percent of the gross weight even of the heaviest fighter. Duration of this concentrated fire? Ten seconds at the utmost.

These are the limits. In spite of the immense importance of aircraft armament, *aircraft designers are confronted with a virtually insoluble problem.* If they develop interceptor fighters of barely adequate endurance by emphasizing rate of climb, then conventional armament is out of date. How can a fighter of this kind successfully combat a powerfully armed bomber?

*

This is where the rocket assumes its spurs in Korea and in extensive tests carried out by most of the world's air powers. As long ago as the end of World War II many experts expressed the opinion that increases in calibre and number of aircraft cannon provided no solution and that rockets must ultimately take the place of cannon. Others sought to save at least the principle of the automatic cannon and introduce automatic rocket launchers. Finally, there were some who adopted the German theory, namely, that of using rockets *and* large-calibre cannon.

It is certain that financial considerations have resulted in a cautious approach in the development of large-calibre cannon. The establishment of stores of ammunition has also compelled the continued wide use of existing calibres. Finally, the trend towards standardization of arms and ammunition under international defence plans may have played a part.

Today, the future tendency is clearly visible, however, and theoretical considerations have been fully confirmed in actual combat. Without wishing to compare air war tactics with those of naval warfare, the rocket will ultimately assert its value and take the place of conventional aircraft armament—just like the torpedo has become the principal weapon of sea warfare.

Slingshots or Precision Weapons?

Headquarters building of the Oerlikon works.

In these days of rearmament and endless newspaper reports of new weapons the average reader is confronted by a tormenting riddle: are the defensive weapons of certain peace-loving countries equal to the offensive weapons of other peace-loving countries? Is it at all possible to stem the advance of a land power's armoured forces or ground attack aircraft? Is there any effective defence against the strategic and tactical bomber units of a sea or air power?

The peaceable citizen reads in his paper of sonic-speed fighters, new giant wonder guns with an effective firing height of more than 43,000 feet, remote-controlled rockets and so on. He takes the accuracy and lethal effect of these much-praised weapons of the peaceful post-war years for granted.

Suddenly this same reader's confidence is shaken by an article in "Time Magazine" for July 23rd, 1951, entitled "Aerial Slingshots." This article will have been read with satisfaction behind the Oder-Neisse line, but with less enthusiasm this side of the curtain, since it sharply criticizes the armament of the latest American fighters. In Korea, it states, one North American F-86 "Sabre" had to spray 1400 rounds of .50 calibre fire from its six machine-guns at a Russian MiG-15 fighter before it went down. The same source also states that rockets now in production are wildly inaccurate, and pilots report an average of only one hit out of 40 tries at stationary ground targets.

Thoughtful people will therefore say: What is the good of all aircraft armament and fast new aircraft—what is the taxpayer paying for?

As for the "wonder gun,"—a reference to a new automatic 120-mm gun—the expert will object that this highly complicated and costly design still has to work on the old "anti-aircraft defence hypothesis": the enemy has to be asleep to get hit: he mustn't change course, height or speed while he is being fired on. This may be all right for large formations of aircraft whose freedom of movement is limited. But what about single aircraft? The new long-range bombers will almost certainly operate singly. Finally, because the new remote-controlled anti-aircraft rockets still have control difficulties to overcome, they have been re-named "misguided missiles."

*

Anyone assailed by doubts can turn to the expert, to the Staff Officer to hear how the last war should have been won, or to the engineer to learn with what new weapons the next war could be decided.

We decided to ask the Chief Engineer of the Arms Division of Oerlikon, Bührle & Co. Machine Tool Works, Zurich. We chose this firm not because it is conveniently located in the vicinity, but because the 20-mm Oerlikon cannon virtually was common property of the belligerents during World War II. About 300,000 were made in the USA, over 30,000 in Great Britain, and the Axis countries used several thousand of them. All this speaks well for the quality of the Oerlikon cannon. We therefore asked this Swiss expert for his opinion of his firm's latest products.

Guns *and* rockets!

We showed him the article from "Time" and asked him whether he thought he had any chance of getting any customers nowadays.

— The Americans' .50 machine gun? One doesn't go hunting elephants with a shot gun. Today's targets, whether in the air or on the ground, are not easily vulnerable. For example, the latest American jet bomber, the Boeing B-47 "Stratojet," has a duralumin wing skin up to 5/8 in. thick, not to mention the armour-plate of ground fighting vehicles. Such targets necessitate the use of H.E. ammunition with time fuses, perhaps even with incendiary charge. The minimum calibre is 20 mm or, even better, 30 mm.

— The inaccuracy of the 5-in. rockets criticized in the "Time" article? The rocket should not be dismissed altogether as a weapon merely on account of this criticism, which may perhaps be justified in the particular case under discussion. We make an 8-cm. rocket which, thanks to the high specific thrust of its propulsive charge, its good aerodynamic qualities and precision in development and production, has a flat trajectory and a high degree of accuracy. It can also be aimed with the same sight as the aircraft guns. With the proximity fuses[1] now under development it will be possible to improve its hitherto unsatisfactory accuracy against air targets. A fighter will in future be able to attack a bomber effectively from an entirely safe distance of approximately 6500 to 13,000 ft.

— In operations against ground targets our armour-piercing hollow-charge rockets have proved entirely satisfactory. They have a very small dispersion and their penetrative power is so great that the explosive gases burn straight through a steel plate 10 in. thick.

— We certainly do not regard the powder rocket as a universal weapon for aircraft. It is impossible to imagine air combat without machine cannon. Cannon are indispensable in the tail of a bomber, since rockets can only be fired with sufficient accuracy in the direction of flight, and a bomber without rear gunners would be defenceless against an enemy attacking from behind. There must therefore be cannon *and* rockets!

This sounds plausible enough, but the validity of these remarks cannot be judged from hearsay alone. We therefore arranged to make a tour of the Oerlikon works with the Chief Engineer, visiting the workshops, prototype department, firing range, etc.

Final inspection of 20-mm anti-aircraft guns on naval mounts.

Machine tools, guns, etc.

Although the name of Oerlikon is well-known today, it might be well to give a brief outline of the history of *Oerlikon*

[1] In the proximity fuse a tiny radar instrument in the nose of the projectile causes the rocket to explode when the distance from the target reaches its minimum or most favourable value.

Bührle & Co. Machine Tool Works.—A real industrial romance.

The Oerlikon Engineering Works had existed at Oerlikon (today a suburb of Zurich) since the middle of the nineteenth century. Early in the present century the firm turned principally to electrical engineering, building among other things the first electric railway in Switzerland. In 1906 the machine tool section was separated from the Oerlikon Engineering Works and made into a new, independent company, the "Oerlikon Machine Tool Works." Up to 1924 the production of machine tools was the firm's main activity, although in 1911 it did design and construct the first Swiss aero engine. However, it lost money on this and gave up engine construction

After the end of World War I the firm got into considerable financial difficulties and sought a purchaser. None was to be found in Switzerland, however. A group of Germans represented by the Magdeburger Werkzeugmaschinenfabrik (Magdeburg Machine Tool Co.) took over the shares in October, 1923, and sent the Magdeburg managing director's right-hand man, *Emil Georg Bührle* to Zurich early in 1924. This was the beginning of a new era for the Oerlikon Machine Tool Works.

Today Bührle is the sole owner of the firm and Oerlikon's rise to fame is intimately connected with his career. Up to the beginning of World War I he was studying literature and history of art and seemed all set to follow a literary career. Called up during the war, he was for a time in command of the machine gun unit of his Dragoon regiment. After the end of the war he stayed on as officer in the Reichswehr, being still undecided as to what career to take up. In 1919 he was quartered on a

Emil Georg Bührle, owner of Oerlikon Machine Tool Works, Bührle & Co.

Magdeburg banker, and became engaged to his daughter. When it came to setting up house the question of his future became acute. Should he go back to his studies? Or continue his career as an officer? Neither prospect attracted him. He therefore took off his uniform and turned to more practical things. He took a commercial training, worked in industry and—made good use of his father-in-law's connections.

At the age of 34 Bührle was sent to Zurich to show what he could do. In Oerlikon he found something approaching chaos: vast stocks of tools, virtually unsaleable now the war was over, but figuring on the books at exaggerated prices; no liquid assets; a mere 80 workers. He saw immediately that the Oerlikon works, in the state they were in, were hardly viable.

Looking round for new items to produce, he heard of the 20-mm Becker cannon, development of which had been started during the war, but never completed, at the plant of the neighbouring Maschinenbau A.G. Seebach, then in liquidation. The former machine gun officer acquired the patents for this cannon for a modest sum and resumed its development. Years of hard work followed for Oerlikon, during which both machine tool production and development of the 20-mm Becker cannon were pursued with typical Swiss thoroughness. By the end of the twenties orders were coming in from China, Finland, Mexico, Bolivia, Argentina, Czechoslovakia, Japan and others. The *Oerlikon cannon* was becoming internationally recognized.

Meanwhile Bührle had succeeded in turning himself from an employee into an independent operator. In 1927 the Magdeburg works got into difficulties and had to sell its Oerlikon interests, and Bührle bought his first shares. By 1929 he was already the principal shareholder and in 1936 he became sole owner, having converted the firm into a private company and himself assuming unlimited liability. The company was renamed Werkzeugmaschinenfabrik Oerlikon, Bührle & Co. (Oerlikon Machine Tool Works, Bührle & Co.). By the early thirties the Oerlikon concern was already independent of the banks and able to finance its own experiments, expansions and interests in other firms. The increase in arms production in the years before the war did the rest: today Oerlikon, Bührle & Co. is financially one of the strongest private enterprises in Switzerland, or even in Europe.

At the outbreak of war orders were in hand from Britain and France for several hundred million francs. During the war large quantities of Oerlikon cannon were built in the U.S.A. and Great Britain. Switzerland's geographical position meant that cannon also had to be supplied to the Axis Powers. Naturally Oerlikon and everything connected with it was blacklisted for this. Without great material and moral reserves the concern could not have withstood this boycott.

Meanwhile Oerlikon had considerably enlarged its interests. A number of firms, such as Contraves A.G. for precision instruments, optics and high frequency engineering; the Welding Electrode Works; the Pilatus Aircraft Works, Stans; the Xamax A.G. for electro-technical articles; the Kopex Machinery Co. for the production of flexible tubes; the Instrument Production Works, Balzers (Liechtenstein) for high vacuum engineering etc., etc., had been founded, some of them before the war. All were grouped together in the holding company. In addition branches were established in France, Italy, South America, India and the U.S.A. Hotels were built, a leading textile concern taken over and shares taken in a bank, the Industrie und Handelsbank, Zurich.

Machine tool assembly hall.

The Oerlikon Arms Works

If you associate the term "arms manufacture" with gun foundries and rolling mills for armour plate, if you imagine sweat-glistening workmen handling streams of

Oerlikon 5 I La/SS 20 mm light A.A. gun for airborne operations : 650 rounds per minute, Contraves computing sight.

molten metal, you will be disappointed on your round of Oerlikon's main factory.

Through modern, airy halls, in which machine tools, pneumatic brakes, hosiery looms and other engineering equipment is being built—briefly, through an area of absolute peace-time activity—we reach the arms workshops. Although laid out on generous lines and equipped with modern tools, this branch of the plant does not seem very large in comparison with the rest. Oerlikon is not a cannon foundry, a gun forge in the conventional sense, such as Vickers, Schneider-Creusot, Skoda or Krupp. For the time being Oerlikon is manufacturing only medium-weight automatic machine-cannon and their ammunition from imported raw materials or is selling manufacturing rights. It is an engineering and production plant for arms and ammunition.

Cannon

The description "engineering and development plant" should not be interpreted too literally. It is a fact that the company is building a moderate quantity of light 20-mm anti-aircraft guns of the type *5 I La/SS*. Incorporating an improved version of the well-known Oerlikon cannon of World War II (type SS, 650 rounds per minute, muzzle velocity 2950 ft/sec) and an ultra-light carriage, this gun is particularly suited to airborne landing operations and similar manœuvres of mobile warfare. The same cannon is also available mounted on a stationary dual mount as an army and naval anti-aircraft gun and in this version bears the designation *12 ZSLa/SS*.

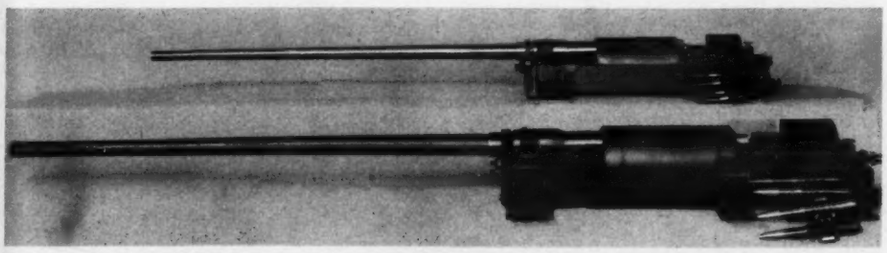
Oerlikon 12 Z S La/SS 20-mm twin A.A. gun : twice 650 rounds per minute, Oerlikon elliptical sight.

Two new developments are undergoing tests at the *firing range*, powerfully protected by concrete and one of the most modern in Europe. With a rate of fire of 1000 rounds per minute, the *5 TG* and *204 GK* 20-mm anti-aircraft guns produce a continuous staccato noise which is quite audible in spite of the thick concrete walls. Electronic instruments with remote readings disclose the relatively high muzzle velocities of the projectiles in the measuring area outside the range: the 5 TG has a velocity of 3,700 ft/sec. and the 204 GK one of 3,450 ft/sec. (1,130 m/sec and 1,050 m/sec).

Much more interesting than these anti-aircraft guns with conventional breech are the *novel high-speed aircraft cannon* in the prototype development section. They reveal the design principle of the German MG 213 C (Mauser) machine cannon which was evolved towards the end of the last war but never saw combat:

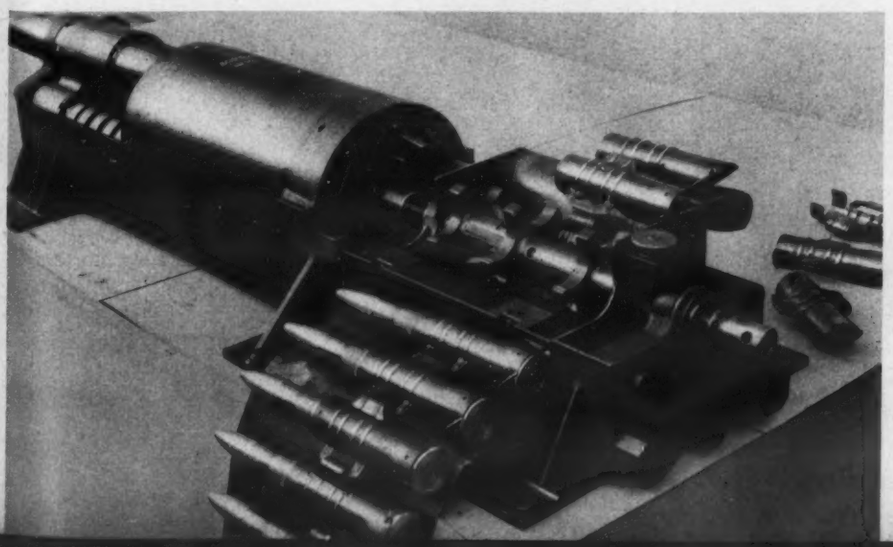
— *206 RK* 20-mm revolver cannon with a rate of fire of 1600 to 1800 rounds per minute and a muzzle velocity of 3,600 ft/sec (1,100 m/sec).
— *302 RK* 30-mm revolver cannon with a rate of fire of 1200 rounds per minute and a muzzle velocity of 3,610 ft/sec (1100 m/sec).

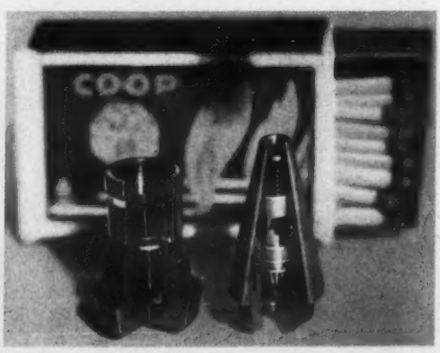
In both weapons, which probably are amongst the most advanced in the world today, the principle of the revolver cannon has been consistently retained and improved. Whereas the German 30-mm cannon of the same type (MG 213 C/30) had a rate of fire of 1150 rounds per minute and a muzzle



The Oerlikon revolver cannon of 30-mm calibre (front) and 20-mm calibre (rear) are developments of the German MG 213 C (Mauser).

Feeding mechanism and the case enclosing the revolving cylinder of the 30-mm revolver cannon. Insertion, detonation and ejection of the cartridges is effected in several simultaneous operations, resulting in a substantially higher rate of fire than possible with conventional breech systems.





The fuses of the Oerlikon 20-mm projectiles are equipped with "centrifugal governors" in order to effect the automatic explosion of rounds missing their targets. At left, a cut-away of a base percussion fuse for armour-piercing shells (centrifugal weights at extreme bottom); right, a point-detonating fuse for high-explosive shells (centrifugal weights in centre).

velocity of only 1,800 ft/sec, the latter value, the so-called V_o, has been doubled in the Oerlikon cannon. Hence the muzzle energy of the projectiles is nearly quadrupled.

The high rate of fire is obtained by means of a "five-shooter" revolving cylinder which is constantly reloaded by a belt from the ammunition box. It functions as follows: insertion of the rounds (in two phases) and ejection of the empty cartridges is effected by a coulisse controlled by the gas pressure of the weapon; the rounds are carried by the revolving cylinder to the position facing the gun barrel and detonated electrically. This system divides into several simultaneous operations a process which in guns with a conventional breech is carried out in a single, and thus relatively lengthy, operation. The result is that the cannon fires faster.

What is the importance of rate of fire and muzzle velocity in aerial combat? The chief engineer explains:

— First of all, the target must be *hit*, secondly, it must be *destroyed*. Rate of fire has a significant effect on both requirements: the probability of effecting a hit increases with the rate of fire, particularly when the attacking aircraft describes a curve and in the case of a barrage; in addition, a greater weight of explosives reaches the target within a given period of time. If the rate of fire is sufficiently high and adequate sighting precision is possible, each increase in the muzzle velocity of the projectile results in an increase in the distance from which an attack may be made; thus, it augments the time available for the attack and also improves the security of the fighter aircraft.

Ammunition

As we walk through the ammunition workshops—spotless, light halls in which women workers predominate—we listen to a concentrated lecture on the effect of ammunition:

— High-performance guns require effective, precision-worked, dependable ammunition. It is no use trying to save money on ammunition. If you consider that a modern jet fighter, say, the North American F-86 "Sabre," costs about $346,000 (though the new F-86D with its increased radar

20-mm armour-piercing shells penetrate 10-mm gauge plates at angles down to 10 degrees.

equipment runs closer to $500,000) complete with equipment, armament and gun-sights, and that the flying and tactical training of a fighter pilot costs another $50,000, it would be nonsensical to haggle about cents in the cost of ammunition. It is ammunition which will make the other investments pay off.

— The development of ammunition is a lengthy and expensive process, but the effort is worth while. The quality of ammunition has been greatly improved since the last war. Improvements in aerodynamic shape have resulted in faster projectile velocities; better charges and fuses have produced greater destructive effects; new incendiary fillings make it possible to set a wing tank on fire with a single hit by a 20-mm shell, irrespective of whether the tank carries gasoline or the less inflammable kerosene.

— Mechanically-operated, automatically detonating fuses provoke, without any great reduction in explosive charge, the explosion of shells which miss their targets. This affords excellent protection to friendly territory.

Projectiles and fuses are demonstrated to us in the manufacturing process. In the 20-mm calibre class, *high-explosive shells and armour-piercing shells* are manufactured. The former are provided with point-detonating percussion fuses (in the nose of the projectile), the latter with base-detonating percussion fuses (underneath the explosive charge). The fuses are so small that three of them could easily be packed in a matchbox. In spite of their miniature size they are fitted with a tiny spring-loaded centrifugal governor which drives the striker into the detonator as soon as the rotation of the shell drops below a given speed. This produces the automatic explosion of the projectile. It is no exaggeration to say that a fighter with modern armament bombards its enemy with something akin to watch movements—at the rate of 80 to 120 per second when firing from all its guns. Since each fuse costs as much as a cheap wrist watch, it is evident that even gunnery practice and "military police actions" are by no means cheap nowadays.

The components of the fuses are manufactured by automatic precision machines and checked with special gauges, since the reliability of the fuse depends upon the narrow tolerance being scrupulously adhered to. Assembly of the fuses is typically Swiss and resembles the work of a watch-maker; it requires nimble fingers and is carried out largely by women.

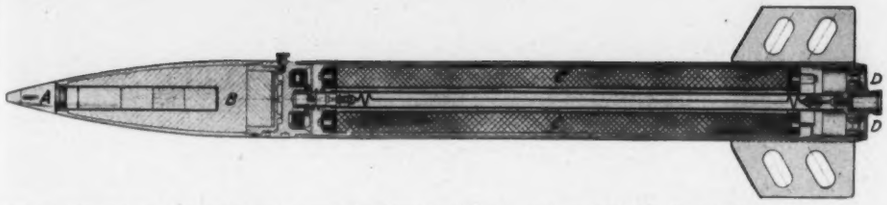
We shall not linger near the machine-tools producing shells and cartridge cases, but a brief glance into one of the numerous laboratories, surrounded by earth walls and used for filling the fuses and projectiles with explosive, is instructive. These sheds are situated at the periphery of the plant. It is obvious that every conceivable safety measure has been taken to enable technicians and workmen surrounded by high explosive to enjoy their well-earned old age pension. For many years, no serious mishap has occurred.

Projectiles of 30-mm calibre are also manufactured, chiefly thin-walled high-explosive shells, called "mine ammunition." They are equipped with fuses similar to those of the 20-mm shells.

Which calibre is preferable? The answer sounds unequivocal but nevertheless contains certain limitations:

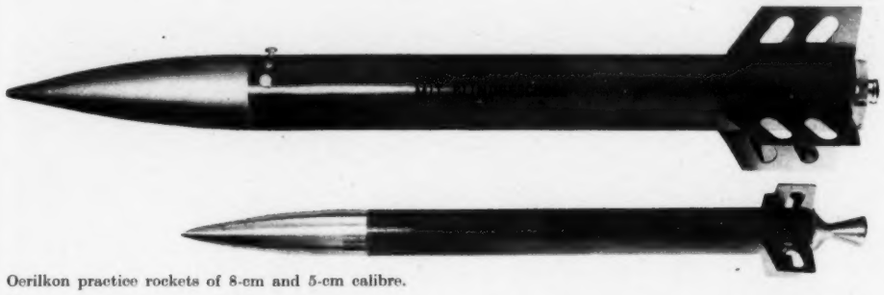
— For aircraft guns shells of 30-mm calibre, such as our mine ammunition, no

A single 20-mm incendiary shell pierces two 3-mm gauge duralumin sheets, the front one of which is inclined, and sets a kerosene tank on fire. The arrangement simulates conditions of a wing fuel tank.

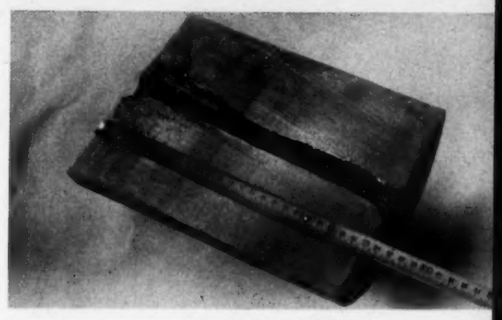


Section through an 8-cm rocket with contact detonating fuse (A) and warhead (B). The tubular propulsive charge (C) is ignited electrically at its forward end ; the electric ignition lead-in passes through the jet duct plate (D).

Effect of a direct hit on a fighter aircraft by a 8-cm rocket (2.2 lb. explosive charge).



Oerilkon practice rockets of 8-cm and 5-cm calibre.



The hollow charge of an 8-cm armour-piercing rocket holes a ten-inch armour-plate.

doubt are the most effective. Its explosive charge is six times as great as that of a 20-mm projectile. And if you consider that our 30-mm revolver cannon has almost double the rate of fire of a conventional 20-mm aircraft cannon, you will see that the weight of fire at the target is nearly twelve times as great. Gun fire of this kind is too much even for the fattest bomber.

— It is true that the installation of 30-mm cannon requires more adaptability from the aircraft designer who may sometimes nostalgically think back to the good old days of the small-bore machine gun. If aircraft do not have sufficient space to house the 30-mm cannon, the 20-mm revolver cannon will prove adequate, but guns of smaller calibre are no longer suitable, as has been shown in Korea.

— The question of whether guns of calibres greater than 30-mm should be developed does not depend upon the destructive effect of the ammunition at the target alone, but even more upon the probability-effectiveness value of the weapon, in other words, upon the rate of fire. The "lethal dose" for a modern heavy bomber is something like 1.65 lbs. (750 gr) of explosive. Whether this dose is imparted with 2, 4 or 6 rounds is less important than the amount of time required to impart it. Size and weight of the gun and the gun mount, as well as the weight of the ammunition, naturally affect flying performance. Larger calibres do not only increase space and weight requirements, but also diminish the rate of fire. Hence it seems preferable to develop *precision rockets in place of large-calibre aircraft guns*, which combine tremendous destructive power with recoilless functioning.

Rockets

This brings us to the Chief Engineer's hobby horse. He shows us the *powder rocket* developed by Oerlikon: diameter 3.15 in. (8 cm) without fins; length about 24 in. (60 cm); gross weight, including propulsive charge, 22 lbs. (10 kg). Several versions of the rocket are being manufactured: a *high-explosive rocket* with an explosive charge of 2.2 lbs. (1 kg) and a contact-detonating fuse in the nose; an *armour-piercing rocket* with a percussion fuse in the base of the hollow explosive charge [2]; and a practice rocket with a dummy warhead or marking charge. All three types can be fired from fighter and tactical attack aircraft, as well as from the ground by anti-aircraft or anti-tank units. This versatility offers great advantages from the point of view of ammunition storage and logistics.

Modern rocket projectiles are no mere objects of pyrotechny but precision weapons. Their internal structure is not as simple as their external aspect would seem to indicate. As in the case of the shells, the fuse is a precision mechanism and comprises a watch movement, an element actuated by the acce-

[2] The hollow charge (or shaped charge), so-called because of a conical metal-sheet lined depression in the explosive charge, provokes a high concentration of the explosive effect in the axis of the projectile.

Experimental version of a rocket-selector-box (for 12 rockets) in the cockpit of an F-51 "Mustang" fighter.

The rocket-release-box (for 24 aircraft rockets) enables rockets to be fired singly or in pairs in successions of predetermined number. It is equipped with marker lights for the purpose of checking the electric ignition circuits and indicating the number of unfired rockets.

Octuple anti-aircraft projector : two-man crew ; Contraves computing sight.

Highly mobile quadruple anti-tank projector : one man crew ; telescopic sight.

leration of the rocket and impeded by an anchor escapement complete with balance, which primes the fuse after the rocket has accomplished a little over 100 yards of its trajectory. The rocket motor comprises eight Laval ducts machined to close tolerances and protected against moisture by plastic skins. Exact weighing of the propulsive charge is essential. Between warhead and propulsive charge there is a compartment containing the electric ignition mechanism for the propulsive charge.

We are also shown the design drawings of a *high-explosive rocket fitted with a proximity fuse* which is now under active development. The warhead of the rocket includes a complete miniature power plant, comprising a gas turbine driven by the propulsive gases and a generator. The latter in turn feeds the microscopic radar instrument of the rocket which continuously measures the distance from the target and ignites the warhead at the most favourable moment.

The effect of such a rocket? A photo shows the havoc wrought on an old Messerschmitt Me 109 fighter on the ground by a direct hit with a single 3.15 in. high-explosive rocket: there isn't much left! But even a rocket with a proximity fuse bursting in close vicinity to a fighter in flight would cause its total destruction. Shaped charge rockets are powerful enough to penetrate a ten-inch armour plate.

What about the probability of securing a hit? Does it take 40 tries to score a single hit, as "Time" has claimed? The engineer smiles. We are used to an inverse proportion, he says. We count on about two misses to a total of 40 hits. In attack distances of 550 to 1100 yds., the rockets have a dispersion of about 10 ‰, *i.e.* half of all the hits will lie within a circle whose diameter is 10 ‰ of the firing distance; at a distance of 1000 yds. this circle will therefore have a diameter of 10 yards. This is a consequence of the high combustion cut-off speed [3] and the excellent flying characteristics of the rocket. It is not possible to state whether other circumstances contribute to the accuracy of the Oerlikon rocket, such as slow rotation, etc. Here we seem to encounter manufacturing secrets. At any rate, we can guess this much: a high cut-off speed is determined by the exhaust velocity of the propulsive gases. In the Oerlikon rocket this velocity probably amounts to more than 8,200 ft/sec (2,500 m/sec). If the weight of the propulsive charge is assumed to be about 6.6 lbs., out of a total rocket weight of 22 lbs. (mass ratio 22 : 15.4), a cut-off velocity of between 2100 ft and 2300 ft. (650 to 700 m/sec) seems to be reasonable for this aerodynamically clean rocket.[4] When fired from aircraft, the forward speed of the latter must be added (650 ft/sec to 800 ft/sec), which minimizes dispersion and at the same time permits the rockets to be launched without guiding rails.

Aircraft Rocket Racks and Projectors

Up to 24 3.15-in. rockets can be suspended from tandem brackets under the wings of fighter or ground-attack aircraft. As a rule they are fired in pairs, one from each wing. For this purpose Oerlikon has developed a *rocket-release box* which is mounted in the cockpit and is also used to check the electric firing circuits. By automatically firing rocket pairs at intervals of one-tenth of a second, it is therefore possible to hurl as much as 53 lbs. of explosive against the enemy within two seconds. This is tremendous fire power.

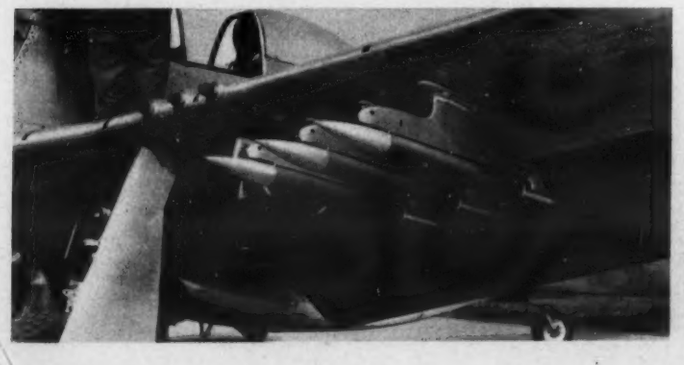
Owing to the excellent aerodynamic shape of the rockets and their suspension the speed

[3] The cut-off speed is the travelling speed of a rocket fired from a stationary position at the moment of termination of combustion of the propulsive charge.

[4] The ideal cut-off speed in a vacuum and without the effect of gravity would thus be:

$$v_t > c. \ln \frac{G_o}{G_o G_t} > 8{,}200 \ln \frac{22}{15{,}4} > 2{,}900 \text{ ft/sec.}$$

Experimental version of the suspension of single 8-cm rockets under the wing of a North American F-51 "Mustang" fighter of the Swiss Air Force.



Tandem racks for 8-cm rockets under the wing of a de Havilland "Vampire" jet fighter of the Swiss Air Force.

penalty of rocket-carrying aircraft is kept within reasonable limits: A Republic F-84E "Thunderjet" carrying 16 or 24 five-inch rockets in clusters under its wings is said to lose up to 100 m.p.h. of its maximum speed; with the Oerlikon rocket this penalty is reported to be reduced by about one-third.

As previously stated, rockets can be fired with precision only in the direction of flight. If they were fired laterally the airstream would provoke a powerful, largely uncompensated deviation. And if they were fired in the direction opposite to that of flight, the rockets would suffer stability disturbances when reaching the absolute speed of "zero."

Oerlikon rockets have been developed simultaneously for anti-aircraft and anti-tank use. This is of particular advantage in the defence of advanced airfields against enemy low-level attacks and tank charges.

The highly mobile Oerlikon octuple projector for *anti-aircraft* purposes is operated by two men and works with a Contraves computing sight. When fired the rockets are guided in rails which are about twice the length of the rockets and can turn through nearly 90°. Maximum height of the rocket is said to be 33,000 ft., but the tactical operational height is probably only 10,000 to 13,000 ft.

For *anti-tank* work Oerlikon has developed a light quadruple projector operated by one man, seconded by an assistant for transport and reloading. A single lever places the projector into firing position, it lowers its tripod mount to the ground, the wheels

An experimental rocket descends on two parachutes: rocket motor at top, rocket body at bottom.

are freed and the projector becomes rotatable through 360 degrees by means of a hand crank. Elevation and azimuth are determined by a telescopic sight; greatest effective firing distance is 1,650 yds (or 1,500 m).

Guided anti-aircraft rockets

Upon completing our tour of the works we are treated to a preview of things to come. The chief engineer discloses a few details of the Oerlikon "guided missiles" which are being built in a branch factory. Equipped with four wings at right angles to each other and with a nitric acid motor, these 16.5 ft.-long anti-aircraft rockets at present have a combustion cut-off velocity of 2,460 ft/sec (750 m/sec) and thus reach altitudes of up to 66,000 ft. Launching weight is 550 lbs. (250 kg) and, equipped with a proximity fuse, they carry a 44 lb. warhead (20 kg).

These rockets have been developed to combat high-flying bombers and are guided to the target by the guide-beam method along a so-called three-point curve. For this purpose a mobile ultra high frequency transmitter, featuring a parabolic reflector and a separate radar sight, has been developed. The rocket gunner constantly maintains the target in the reticule of his sight and thus directs the rocket riding the guide beam automatically to the target. The rocket launcher is mobile, being mounted on wheels.

For the time being this guided missile development no doubt is still in its infancy. It is the aim of the manufacturers to turn "misguided missiles" into reliable guided missiles. Problems of guided beam control present many difficulties, and rocket experiments are costly. In any case, no effort is spared to salvage experimental rockets with as little damage as possible: following termination of combustion, the "airframe" and the rocket motor become detached and descend separately on parachutes.

*

We have now completed our inspection tour of an arms factory, having learned what the plant is building as well as something of the management's immediate projects. The Oerlikon factory is no mammoth operation of the kind that existed in pre-war years in many of the great nations for the manufacture of naval guns and long-range artillery. Nevertheless Oerlikon is a big concern, the climax of whose ambition is represented by the high precision and dependability of its guns. In this field it has won world-wide recognition.

An American report now compares the aircraft armament used in Korea with slingshots. This striking statement induces a whole train of thought: after the war the U.S.A. and recently also Britain have turned out a number of remarkable giant aircraft, apparently without taking into account that power plant development had lagged far behind airframe design. Inevitably, these aircraft proved to be disappointing. In the whirl of the rearmament race numerous high-speed first-line aircraft of outstanding quality are now being built, and in the view of the manufacturers high speed and good flying characteristics alone appear to be sufficient to make the aircraft a powerful striking weapon. This seems to have been a fatal error: after all, a combat aircraft, regardless of its design, is merely the carrier of a weapon. Modern weapons, for offence and defence, must therefore be developed for these modern aircraft. The old weapons have been relegated to the rank of slingshots by advances in aeronautical engineering. But new weapons are coming along.

Launching of an Oerlikon guided rocket prototype: nitric acid motor; four wings at right angles; take-off weight, 550 lbs.

The parabolic reflector of the guide-beam transmitter of the Oerlikon guided rocket (bottom) and the antenna of the radar sight (top) are mounted separately on the swivelling arm of a rotating mobile mount.

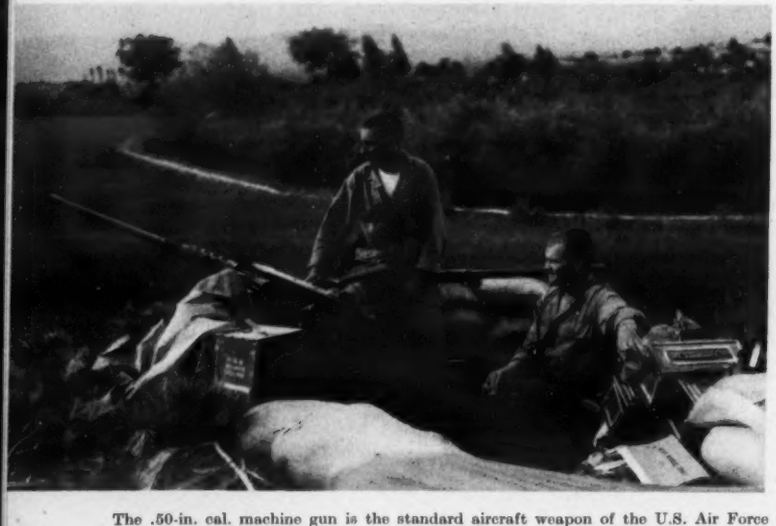
Air Weapons in the U.S.

BY CHRIS ROBERTS, WASHINGTON

The United States Air Force and Naval Aviation have jointly established a world-wide reputation for enterprise and ingenuity in fashioning radical new aircraft and placing them in service with surprising speed. The first U.S. Navy carrier squadron (VF-17A) to be equipped with jet fighters (McDonnell FH-1 "Phantom") received its machines in the fall of 1947 and swept-wing fighters (North American F-86A "Sabre") went into squadron service (1st Fighter Group, March Air Force Base, Calif.) with the USAF late in 1948, both events antedating their counterparts in other services by a number of years.

This willingness to try new things and eagerness for rapid progress inherently produces unexpected difficulties and delays, which the two Services attack with vigor and philosophic calm. In the airplane field it is the regular order of business. But no such optimistic resolution is to be found in the field of aircraft armament in either of the Services.

There is one part of the airplane that the high command will not gamble with: its guns. In this special field both branches of the Service ask firstly for dependability—all other qualities falling behind in insignificant ratio. This tiny island of conservatism in a sea of optimism stands out boldly as an intelligent rebuke to the adolescent glamour of modern air force personnel. Here is the hard core of air combat, the foundation stone of the aerial weapon and, in the U.S. at least, a forbidden zone for the tinkerers and restless experimenters.



The .50-in. cal. machine gun is the standard aircraft weapon of the U.S. Air Force but is standard equipment also with the U.S. Army for ground and anti-aircraft purposes. The gun is shown in use by U.S. forces in Korea.

A quadruple mount .50-in. anti-aircraft gun on the periphery of a U.S. airfield in Korea. It is intended to combat low-flying tactical aircraft.

The standard aircraft weapon in the U.S. Air Force is the *.50 in. calibre machine gun*, a practice that has not changed in some 15 years. Standard fighter armament is six of these guns, each with 300 rounds of ammunition. Unquestionably, this is the most reliable weapon available, and only an electronic calculating machine could compile the astronomical total number of rounds fired from this gun in air combat. It is this unmatched, proved record of reliability that permits this ancient weapon to continue to be installed in the very latest U.S. combat aircraft coming from the assembly lines.

Development work on the .50-calibre aircraft machine gun during its life belies its hoary vintage, however, and the current weapon is a far cry from its prototype. World War II U.S. combat aircraft mounted the Model M2 with a rate of fire of about 800 rounds per minute; electrical gun heaters were used for high altitude and special high-temperature lubricants for low-altitude continuous firing. Wartime research and development by the Army Ordnance Department, which has cognizance of all weapons used by the Air Force, produced decided improvements in the .50-cal. aircraft machine gun, and by 1944 the M3 model was available with a rate of fire of 1200 rounds per minute, a 50-percent improvement that is extraordinary in weapons development. The M3, however, was too late for World War II production line installation, and it did not come into service until the advent of the Lockheed P-80B "Shooting Star" and Republic P-84B "Thunderjet" models in 1947. Since that time it has been the standard fighter weapon in the Air Force. The increasing altitude of operation and the greater rate of fire have been accommodated by continuous improvements in heaters and special lubricants, the latter now including silicones.

The consistency in policy between the Air Force and Naval Aviation regarding the sanctity of *reliability* in aircraft weapons to the exclusion of most other attributes ends with the *choice* of guns. Naval Aviation uses four *20-mm cannon* as standard fighter armament, a practice started with the first carrier jet fighter and continued in subsequent models. Here, too, important improvements have been made since World War II; whereas the Model M2 20-mm cannon had a rate of fire of 600 rounds per minute, the newly-developed M3 has improved this to 750-800 rounds, extraordinarily high for an explosive shell-firing machine weapon. Aircraft armament in the Navy is under cognizance of the Navy Bureau of Ordnance, but the Army and Navy versions of the M3 are practically identical, with the burden of the development work having been carried by the Army Ordnance Department.

It seems impossible to obtain a clear, official statement from the Services as to why the Air Force uses the .50-cal. weapon and Naval Aviation the 20-mm cannon. Both Services eagerly pile up tons of verbiage on the subject, centering about "the peculiar requirements of the two Services" or their "unique combat conditions," etc., but the sum total of the debate seems to be personal opinion of the officers in charge of the procurement programs, which shows a continuing unanimity as the offices change hands. Suffice it to say that the Air Force prefers a greater weight of fire at close range, the Navy a longer range at lesser weight of fire. The .50-cal. machine gun has an effective air combat range of about 750 yards, whereas the 20-mm is accurately used up to 1500 yards. The latter gun, of course, uses an explosive shell and the combination of its high muzzle velocity with this feature produces a really destructive weapon. No further development work has been done of .50-cal. cartridges since

World War II, but very great improvements are now available in the 20-mm charge and its striking energy is now about double that of the wartime shell.

The Army Ordnance Department and Navy Bureau of Ordnance co-ordinated closely during the late war years on the development of a *.60-cal. aircraft machine gun*, which is roughly a 15-mm gun. The Air Force and Naval Aviation experimented extensively with the gun in the post-war years. The Navy conducted firing tests with a Grumman F8F "Bearcat" fighter and, at one time, specified the .60-cal. weapon for the Grumman F9F "Panther" jet fighter. However, Bureau of Aeronautics insisted that the gun be acceptable only when it became fully interchangeable with the standard 20-mm weapon, which has not yet been achieved, although work is still in progress.

Air Force objection to the gun is its comparatively low rate of fire as compared with the .50-cal., although its weight of fire is comparable. The .60-cal. has produced a rate of 900 rounds per minute in ground tests, but the new M3 20-mm with its 800 r.p.m. so closely approaches this and has the added feature of explosive shells as to make it the more desirable gun. The Air Force has specified the M3 cannon in the new Northrop F-89 "Scorpion" all-weather fighter, the only cannon-equipped fighter in the Air Force, and has obtained excellent results.

The *37-mm cannon*, which was developed satisfactorily during World War II for aircraft, has apparently disappeared for any future installations because of its slow rate of fire. While it is a terribly destructive shell when it hits, the mathematicians have determined that its probability-effectiveness value is lower than either of the currently-standard weapons. The 37-mm cannon was installed briefly in early versions of the Lockheed P-38 "Lightning" fighters but was later replaced by the more satisfactory 20-mm cannon. It remained in use on the Bell P-39 "Airacobra," particularly in those versions shipped to the Russians, who found it an ideal air-to-ground strafing weapon.

In development now is a *one-inch (25.4-mm) aircraft cannon* which the Services hope will carry the hitting power of the 37-mm with the high rate of fire of the 20-mm, but Service insistence on absolute reliability in aircraft guns makes their development a very, very long process in which impatience has no place. A *32-mm cannon* is also being studied, but both types have a long development road ahead of them and nothing is anticipated in the way of a finished weapon for five years.

*

In the field of *anti-aircraft defense in the U.S. Army*, the post-war emphasis has been on the development of "weapon systems" rather than solely on the weapons themselves. The anti-aircraft defense installation of today contains a complex combination of anti-aircraft weapons linked with ground cables to the gunfire director and the radar warning system. This complex arrangement is further co-ordinated with fighter control in the area to produce an *integrated anti-aircraft weapons system*. The development of such systems is the responsibility of the joint Weapons Systems Evaluation Board, which draws its mathematical calculations from the Research and Development Board and its hard-headed practical information from the Army and the Ordnance Department.

The defense-in-depth principle is followed in the arrangement of an anti-aircraft installation around a vital installation; *i.e.*, it cannot merely be assumed that an enemy bomber will fly over at 30,000 ft. and drop an atom bomb: every conceivable type of attack must be considered. It usually comes as a surprise to the layman to learn that weapons decrease in calibre inwards towards the target, rather than the reverse. This is in accordance with the principle that the enemy bomber must release its bombs farther away from the target the higher its altitude, so that the *heavy 120-mm anti-aircraft batteries* are located several miles away from the target to be protected. Closer to the target are the *90-mm weapons* and closer still the *40-mm* and *.50-cal. weapons*. This system is surrounded on its outer periphery not by a huge 240-mm anti-aircraft gun, as might be supposed, but by a ring of .50-cal. guns to handle low-approach ground strafing enemy aircraft who race in at ground level to avoid detection. Throughout this weapons system, the principle is observed

The 40-mm Bofors standard anti-aircraft gun has been greatly improved since the war. One of these guns is shown in a sandbag barricade near the front lines in Korea.

Twin self-propelled Bofors 40-mm guns, mounted on an M-19 ack-ack tank, are used both for AA defence and horizontal firing. The M-19 is about to move to the Korean front to smash a Communist road block near Yongsan.

that the most efficient gun to use is the smallest calibre that will do the job; *i.e.* the big 120-mm guns are wasted on enemy aircraft coming in at low altitude, etc.

Improvements are being made constantly by the Army Ordnance Department at its Aberdeen (Md.) Proving Ground, a huge reservation echoing daily to the thunderous explosion of heavy guns and the sharp staccato of small-arms fire. The greatest post-war developments in the anti-aircraft weapons field, however, have been made in fire control systems. For example, the *standard 40-mm anti-aircraft cannon*, the so-called "Bofors" developed during World War II (which was firmly rejected by both the U.S. and the British when Nils Bofors first offered his gun!), is now equipped with a fire-director system and a computing gunsight. Estimated enemy aircraft slant range, speed and course (produced by the radar warning net) are

A 90-mm anti-aircraft gun crew of the First Cavalry Division, U.S. Army, goes into action against Communist ground forces in Korea.

U.S. Army's heavy-weight : a battery of four power-loaded 120-mm A.A. guns in position. Effective striking altitude is 48,000 feet.

fed into the computer and the gun is aimed and trailed automatically according to this information.

Most important new fire control system developed in the anti-aircraft field is the radar-controlled, automatic-firing system mounted on the *new "Skysweeper" anti-aircraft gun.* This is a 75-mm weapon with a high rate of fire, although its effective altitude is somewhat limited due to its calibre. It more than compensates for this comparatively small shell by its astonishing accuracy and fully-automatic operation. It can be completely remotely controlled by a gun director, doing its own detection, laying and firing. The gun, developed over many years of intensive research, is now in vast quantity production in the U.S. and will shortly become a standard anti-aircraft weapon capable of handling supersonic enemy aircraft and even missiles. Its full potential development is only now beginning and it is the prototype for a *whole new family of anti-missile guns now under development.*

The U.S. Army has not abandoned the familiar *.50-cal. machine gun as a weapon against low-flying enemy tactical aircraft*, and a power-driven quadruple-mount unit is now standard equipment in Army units. It is either mounted on a half-track vehicle as a self-propelled gun, or may be disassembled and set up in a revetment as a fixed gun.

The 40-mm anti-aircraft weapon, used in either a single towed carriage artillery piece or mounted in a dual mount on a self-propelled carriage, is an effective weapon up to about 10,000 ft., firing high-explosive ammunition with contact-detonating fuse either with or without tracer.

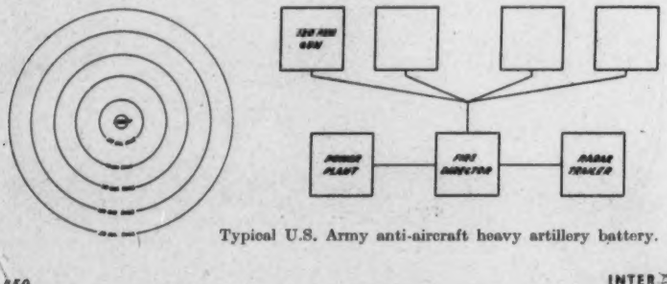
The 90-mm anti-aircraft gun is one of the most versatile ordnance pieces in the U.S. arsenal. It is moved on a towed carriage in its standard 31,000-lb. version, but a new light-weight version designed for air transportability weighs only 19,000 lbs. It has been parachuted successfully from a Fairchild "Packet" transport. It fires a 23-lb. high-explosive round fitted with a mechanical timer, or the highly-successful VT ("proximity") fused missile. It is hand-loaded and its rate of fire of about 25 rounds per minute is determined by the skill of the crew.

The big 120-mm anti-aircraft weapon weighs 60,000 lbs. and requires 15 men for its installation and operation. It fires a 50-lb. high-explosive shell armed with either VT or mechanical timer fuse. It is moved by a towed carriage and has a power-operated loading system enabling the average crew to operate it at the rate of 12/15 rounds per minute. It's effective *striking altitude of about 48,000 ft.* enables it to cope with practically all current aircraft that may come within range, certainly any bombardment type.

It has been a fundamental principle with the Army Ordnance Department that all anti-aircraft weapons must also be adaptable as straight ground artillery pieces and for this reason all of these weapons have a full elevation travel of 90 deg. permitting their barrels to be lowered for horizontal fire when required.

It will have been noted that there has been no discussion in the foregoing of guided missiles as aircraft and anti-aircraft weapons, but this is a vast subject unto itself and, in the United States at least, a highly secret one. The foregoing comprises a progress report on the subject with reference only to those weapons in being and in readiness for instant field use, a situation not parallel in the guided missile field in the U.S. Surface-to-air missile work in the U.S. is still wholly in the development phase and there are no surface-to-air missile types in quantity production for arsenal stowage preparatory to field use.

Typical U.S. anti-aircraft defense-in-depth system. Light guns are near target, heaviest guns on outside periphery, again surrounded by a ring of light weapons for defense against low-flying tactical aircraft.



Typical U.S. Army anti-aircraft heavy artillery battery.

U.S. Anti-Aircraft Weapons

Gun	Rate of fire	Effective altitude	Carriage	Loading
Single .50-cal.	1000	2,500 ft.	None	Belt feed
Quadruple .50-cal.	4000	2,500 ft.	Self-propelled	Belt feed
Single 40-mm	120	10,000 ft.	Towed	Hand, clips
Double 40-mm	240	10,000 ft.	Self-propelled	Hand, clips
90-mm	25	30,000 ft.	Towed	Hand, single round
120-mm	12/15	48,000 ft.	Towed	Power, single round

Aircraft Rockets

Rocket projectiles fired from aircraft have become a widely-used type of weapon since the last war. They can be classified into two general categories, namely, unguided rockets and guided rockets.

Unguided Rockets

Unguided rocket projectiles consist essentially of a warhead and a propulsion unit. During flight they are stabilized either by fins or by rotation about their longitudinal axis; their trajectory is a ballistic curve. They always operate on solid fuel, the tubular propulsive unit simultaneously forming the fuel compartment and the combustion chamber. The compressed fuel is composed in such a manner as to ensure uniform combustion, *i.e.*, producing the same amount of propulsive gases in any given time. These gases exhaust into the atmosphere at the rear of the projectile through one or more nozzles. In rotationally stabilized rockets the rotation of the projectile is provoked by a number of swirl nozzles arranged obliquely within a circle concentric with the rocket axis.

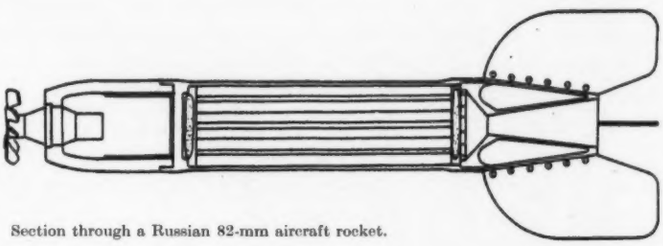
Depending upon its use, the warhead can be fitted with a percussion fuse, a time fuse or a proximity fuse. According to the effect desired, thick-walled warheads with hardened points or thin-walled high-explosive warheads or hollow-charge warheads can be employed. In most rocket types one and the same propulsion unit can be fitted with different kinds of warhead.

The structure of the unguided aircraft rocket is relatively simple. The effect of the rocket roughly corresponds to that of a heavy artillery shell and therefore is much greater than that of conventional aircraft cannon. Owing to the absence of recoil in launching the rocket, the aircraft structure is not subjected to heavy stresses, so that lighter types of aircraft can be equipped with rockets and used as flying artillery. One disadvantage of most aircraft rockets lies in their much greater rate of dispersion as compared with aircraft cannon. This fact and the relatively small maximum velocity of most rockets explains the fact that rockets have so far been used almost exclusively against targets on the ground. A number of new types of unguided rockets possess characteristics enabling them to be used as air-to-air weapons with a considerable chance of success. *Table 1* shows the major types of unguided rocket known at present.

The idea of using rockets for the armament of aircraft was conceived as long ago as World War I. The rockets of that time, derived from civil fireworks, were not effective and the project was dropped. In World War II the Russians were the first to use aircraft rockets with any degree of success: rockets were launched from Ilyushin "Stormovik" assault bombers against ground targets. The Russian rockets had a calibre of 3.2 ins., four stabilizing fins and a single jet nozzle in the centre. The thick-walled warhead screwed on to the propulsion unit had a percussion fuse which was armed by the air flow.

The other belligerent powers quickly followed the Russian example and created their own aircraft rockets. In England an aircraft rocket stabilized by wings was developed from an anti-aircraft rocket. It had a calibre of 3 in. and was launched from long guiding rails on the wing underside against ships, vehicles and other pin-point targets. Today the Royal Air Force has three rocket types: the three-inch rocket with a warhead weighing 60 lbs.; the five-inch rocket with a warhead of the same weight; and another rocket with a warhead of 170 lbs. All three types reach relatively low speed, and their accuracy is said to be more or less debatable.

The first American aircraft rocket had a calibre of 4.5 ins. and was designated *M 8*. It was stabilized by folding tail fins and fired from tubes. Its accuracy was quite inadequate and its dispersion amounted to about $14^0/_{00}$. Owing to its low speed and high rate of dispersion its tactical range was limited to 550 yards.



Section through a Russian 82-mm aircraft rocket.

Three-inch rockets on a Bristol "Beaufighter" of R.A.F. Coastal Command.

Recent British rockets carried by a Hawker "Sea Fury" fighter.

The U.S. Navy's Douglas AD-1 "Skyraider" carrier-borne naval strike aircraft (with dive brakes extended) is armed with twelve "Holy Moses" five-inch rockets, each with a 45 - 16. warhead, and two "Tiny Tim" twelve-inch rockets, each with a 600-lb. explosive charge. Owing to its powerful rocket jet the "Tiny Tim" is fired by a cable after it has dropped about 3-4 ft. away from the aircraft.

Several improved developments of this model were evolved in due course, including the "*Super M 8*" which had a length of 5.9 ft. but did not go into combat operations before the end of the war.

With a dispersion of only 3.5‰, the American *3.5-in. AR* aircraft rocket had a much better accuracy than the *M 8*. It carried a massive armour-piercing steel warhead and was put into quantity production in autumn, 1943.

By combining the propulsion unit of the 3.5-in *AR* with a larger warhead, the *5-in. AR* was created at the end of 1943. The speed of this type was insufficient, however, because the propulsive power was not adequate for the heavy warhead. A more powerful propulsion unit was then created and the result designated *5-in. HVAR* (High Velocity Aircraft Rocket). This rocket, which was christened "Holy Moses" by the troops, can be fitted with a variety of warheads and is the standard rocket of the U.S. Air Force. With a shaped charge it can hole armour plating up to 11 in. in thickness.

In addition to "Holy Moses," the USAF and the U.S. Navy today use "*Tiny Tim*" rockets, developed towards the end of the last war and particularly suitable for use against warships. With a diameter of 12 in. and a launching weight of 1,280 lbs., the "Tiny Tim" is the largest unguided rocket to become operational so far.

For air-to-air use all these rockets are too slow and too inaccurate. Towards the end of World War II the Germans fitted fighter aircraft with heavy rotationally stabilized rockets, one of which was the "*21-cm Wgr.*" These rockets were soon found to be relatively unsuitable for aerial combat, and a small rocket, the *R 4 M* was developed for the purpose. It had a calibre of 2.2 in. (5.5 cm), folding wings and was intended to be fired from an automatic launcher ("*Raketen-Automat RA 55*") at a rate of 300 rockets per minute. Apart from isolated experimental operations, the R 4 M did not see war service.

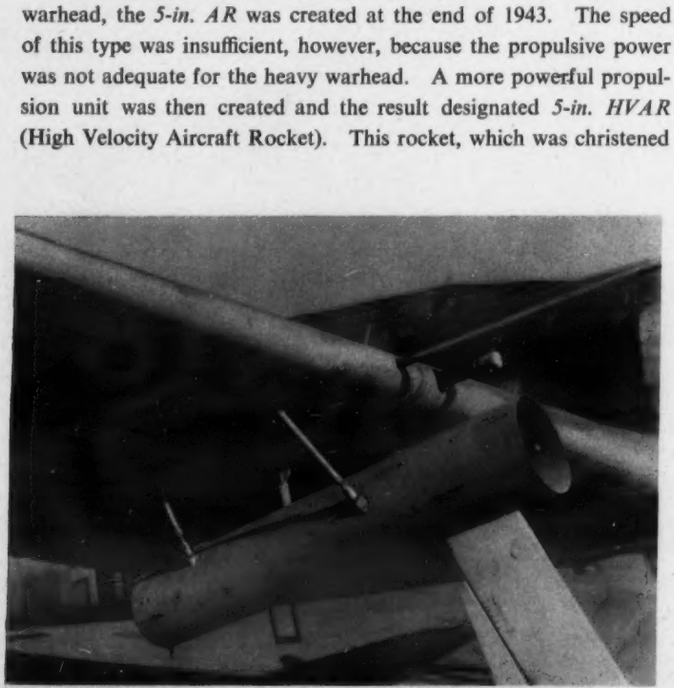
Three rocket types suitable for air-to-air use are known today. The "*Mighty Mouse*" of the U.S. Air Force, which has a calibre of 3 in., is undergoing tactical tests. It has folding wings and can therefore be fired from tubes. The *Oerlikon 8-cm rocket* is about the same size as the "Mighty Mouse" and, with 2,300 ft/sec., has a remarkable velocity and uncommon accuracy. The *Hughes MX-904*, which is larger than the types just mentioned, is claimed to reach Mach = 2.5 and is to be used experimentally as part of the defensive armament of the Convair B-36 giant bomber.

Guided rockets

Guided aircraft rockets are substantially more complicated and require a much greater manufacturing effort than unguided rockets. In addition to the warhead and propulsion unit they must be fitted with controls and remote guiding systems. Most rockets of this type have liquid fuel motors, in which fuel tanks and combustion chamber are separated. The fuel is fed into the combustion chamber either by compressed gas or mechanically driven pump. Hence, the power plant installation is relatively complex. On the other hand, much longer combustion periods can be attained than with solid fuels. Guided rockets of short flight duration can also be equipped with solid fuel units.

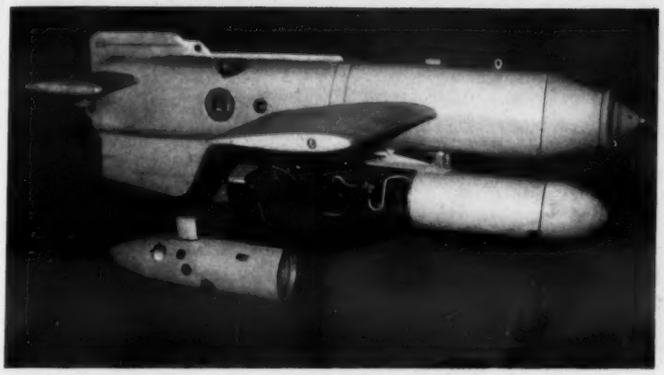
For the absorption of centrifugal accelerations in curves, guided rockets must be equipped with supporting surfaces. To enable the rocket to describe curves without rolling, cruciform or annular surfaces are frequently used. The control forces are generated either by aerodynamic rudders or by changes in the direction of the jet axis. The rocket is guided to the target by radio-electric remote control from the launching aircraft, but it is also possible to instal a target-homing devise in the missile.

Table 2 contains the principal data of a number of guided aircraft rockets. The first of the kind was developed in Germany during World War II and employed against air and ground targets. From 1943 onwards, the *Henschel Hs 293* was used chiefly against ships; it was a small, crewless aircraft with a warhead of nearly 1100 lbs. The power plant, a Walter bi-fuel rocket, was arranged in a pod under the fuselage. The jet nozzle was inclined in such a way as to have the thrust line pass through the centre of gravity of the missile. The Hs 293 was guided from the launching aircraft by radio. To facilitate



A 21-cm rocket under the wing of a *Luftwaffe* Focke-Wulf Fw 190 fighter.

A salvo of 16 "Mighty Mouse" three-inch rockets shortly after being fired from a North American F-86D "Sabre" jet fighter.



The German Henschel Hs 293 guided aircraft rocket went into service in 1943 and was used predominantly against ships.

The U.S. KU 2 N "Gorgon" guided rocket was intended for use against aircraft, ships and ground targets. It was of the canard type and had a proximity fuse.

observation, tracer elements were incorporated at the tips of the rectangular wings.

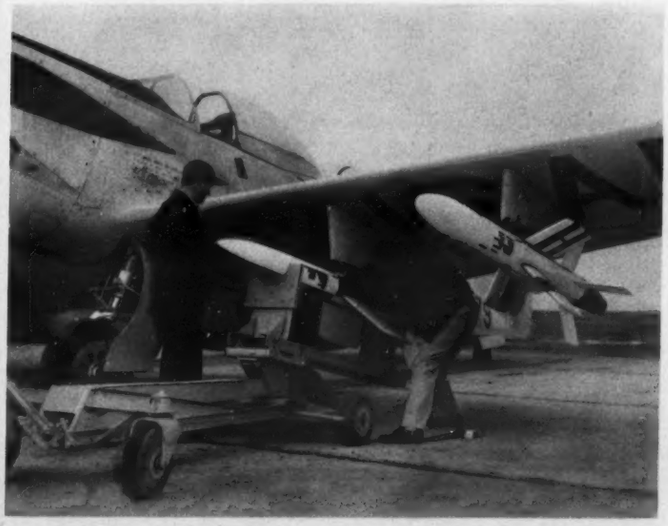
The somewhat smaller *Henschel Hs 298* was designed for air-to-air use. It was similar in design but was somewhat smaller; it had swept wings and a solid fuel rocket. The warhead was equipped with a proximity fuse, and the missile was radio-controlled. The Hs 298 did not go into operational service.

Another air-to-air rocket was the *BMW X-4*, a small, streamlined missile with cruciform wings and a liquid fuel rocket motor [1]. The X-4 was also to be guided from the launching aircraft but electrically via two insulated wires measuring 3.3 miles and paid out from coils at the wing tips of the X-4. An even smaller version, the *X-7*, was intended for use against ground targets, notably tanks. With a launching weight of only 20 lbs., the X-7 probably is the smallest guided missile ever built. It had a two-stage solid fuel rocket. Neither the X-4 nor the X-7 went into tactical service.

Of the guided aircraft rockets developed in the United States during the war, mention is made only of the Navy's KU 2 N "Gorgon." It had a liquid fuel rocket motor and was intended for use against aerial targets. Control was by radio. Several versions of the "Gorgon" were later used for experimental purposes and as target aircraft, including a model with ram-jet propulsion ("Gorgon IV") [2]. The latest American air-to-air rocket is the Ryan "*Firebird.*" It has a cylindrical fuselage of about 8 ins. diameter and 10 ft. length, swept cruciform wings of about 32 ins. and swept cruciform tail fins. Upon launching the "Firebird" receives its initial acceleration by a booster rocket. The latter is jettisoned when combustion is terminated and a bi-fuel rocket goes into action. The missile is equipped with a target-homing device and proximity fuse. *rw.*

[1] Cf. "X-4, Germany's Smallest Liquid Rocket" by H. Gartmann, "INTERAVIA, Review of World Aviation," September, 1949, pp. 553-555.

The most recent American air-to-air guided rocket is the Ryan "Firebird." It is about 10 feet long and has cruciform wings and tail fins. Picture shows "Firebirds" under the wings of a North American F-82 "Twin Mustang" twin-engined long-range fighter.



[2] Other American types: McDonnell KSD "Gargoyle," a small low-wing monoplane with butterfly tail and liquid fuel rocket; Douglas "ROC," with annular supporting surface.

Table 1 : Unguided Aircraft Rockets

Type	Calibre in.	Length in.	Launching weight lbs.	Warhead lbs.	Propulsive charge lbs.	Top speed ft/sec.
USSR.....	3.2	23	13.4	0.84*	2.2	1,150
Wgr.	8.3	43	176	—	—	1,050
R4M.....	2.2	—	—	0.99*	—	—
M8	4.51	33	38.5	4.00*	4.6	855
Super M.8	4.51	70	104	40	—	1,310
3.5-inch-AR	3.5	55	55	20	8.6	1,180
5-inch-AR	5.0	—	79	45.0	8.6	690
5-inch-HVAR ..	5.0	76	140.0	45.0	24.0	1,380
"Tiny Tim"	12.0	—	1,280	595	145	790
"Mighty Mouse".	3.0	—	—	—	—	—
MX 904	—	—	75	9.9*	—	2,460
Oerlikon	3.1	—	22	—	—	2,300

* Explosive charge only.

Table 2 : Guided Aircraft Rockets

Type	Span in.	Length in.	Launching weight lbs.	Warhead lbs.	Fuel lbs.	Thrust duration secs.	Thrust lbs.	Top speed ft/sec.
Hs 293.....	114	138	1,730	1,100	150	12	1,323	475
Hs 298.....	51	79	210	55	70	5	330	855
						20	110	
X-4	33	80	132	55	18.7	22	310-0	920
X-7	—	30	20	5.5	14.1	8	11	330

Guided Anti-Aircraft Missiles

Combating aircraft from the ground has always been an uncertain and tedious business. The crux of the problem is that projectiles fired from the ground take time to travel to the aircraft and that the aircraft in turn travel a certain distance during this time. This distance can be calculated precisely—provided that the aircraft stays on course and maintains its speed during the travelling time of the projectile. As long as projectile travelling times are short and aircraft fly at relatively low speeds, this method produces a reasonable hitting probability, especially if sighting errors are compensated by a rapid rate of fire.

Advances in aeronautical engineering have resulted in aircraft flying much faster and higher than they did only a few years ago. While the effectiveness of anti-aircraft artillery was not very great even a few years back, it has become entirely insufficient to cope with today's high-speed bombers. Why? One reason is that the lead distances in sighting the guns have become enormous owing to greater operational heights and speeds of the aircraft. The probability of aircraft deviating from their course grows with increasing lead distances. Once the projectile leaves the muzzle of its gun, its trajectory can no longer be corrected. An aircraft flying at 30,000 ft., for example, will require about 30 secs. to be reached by the anti-aircraft shell. In this time a bomber flying at about 500 m.p.h. will have covered over 4.1 miles. Assuming that the shell is fitted with a proximity fuse and has an effective explosive power within a circle of 30 ft. radius, and assuming that the shell arrives at the calculated point of interception at exactly the right time, the aircraft must not deviate more than 10 ft. from its theoretical course if it is to be brought down. This means that the pilot must not turn more than one-twelfth of a degree from his course after the shell is fired. Apart from that, it is not possible to tell the course of the target with such great accuracy at 30,000 ft. Furthermore, only very heavy anti-aircraft guns can be used for such heights, and the low rates of fire of these guns do not make possible a concentration of fire sufficient to compensate for the poor hitting probability of each individual round.

These disadvantages of anti-aircraft artillery led to the creation of a new type of weapon during World War II, namely *anti-aircraft guided weapons*. By definition a guided weapon is a crewless missile whose trajectory can be influenced after launching. This makes it possible to direct the missile to the target, and each evasive action on the latter's part is immediately counteracted by correcting the trajectory of the guided weapon. The missile can be directed either from outside or else by guiding mechanism partly or fully housed in its interior.

For the propulsion of guided missiles, which must be quickly accelerated to high speeds to enable them to follow their target, *rocket motors* are used exclusively. So as to make possible flight along a straight line and to absorb the centrifugal forces occuring in turns, the guided missile must be provided with supporting surfaces. In most cases four wings arranged cross-wise or annular supporting surfaces are employed, so that the rocket can curve in every direction without having to turn about its longitudinal axis. To control the rocket, aerodynamic rudders may be provided, or the rocket jet may be influenced by deflecting the nozzle or by means of rudders located in the jet. The size of the guided missile depends largely upon the fuel supply and therefore on the required speed and range.

For guided anti-aircraft weapons two control systems are mainly employed today: an impulse system and a guide beam system.

In the *impulse system* wireless command impulses are continuously conveyed to the missile from the ground. These impulses affect the trajectory of the weapon through the control elements. With this system the installations needed aboard the guided missile are greatly simplified; the equipment merely serves to transmit the command impulses to the actual controls of the rocket. The impulse system requires accurate observation both of the target and the missile. Visual observation being limited to short distances and low speeds, complicated observation equipment is required for a modern anti-aircraft defence system.

From the ground installation of the impulse command system target *F* is measured by radar instrument *A*; the data thus obtained is continuously fed to computor *R*. As soon as the target is in the most favourable position, the computor launches the guided missile from ramp *C*. From that moment onwards missile *L* is followed by a second radar instrument *B*, which also feeds its data to the computor. The latter computes the corrections necessary to provoke interception of the target by the guided missile. Corresponding impulse commands are then conveyed to the guided missile by transmitter *S*.

In the *guide beam system* only target *F* is followed by a radar instrument *R*. Transmitter *S* controlled by the radar instrument transmits a radio beam which remains continuously trained on the target. From launcher *C* the guided missile is led into the beam and rides this beam until it reaches its target.

Ground equipment is much simpler in the guide beam system than the impulse command system. On the other hand, the guided missile itself must possess a higher degree of "intelligence" in order to maintain itself within the guide beam. For this purpose the guiding system of the rocket must always maintain the rocket at an angle of

Diagram of the command impulse system : A and B, radar instruments ; C, launching ramp ; R, computor ; S, transmitter ; F, target ; L, guided missile.

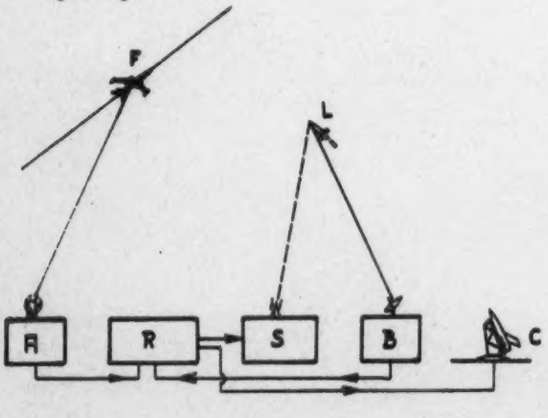
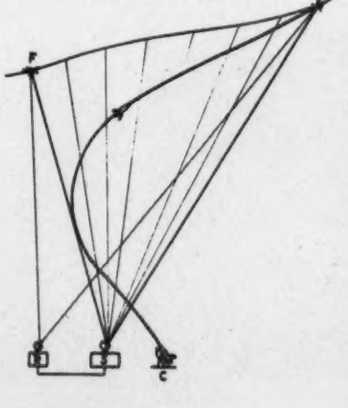


Diagram of the guide beam system : R, radar instrument ; S, guide beam transmitter ; C, launching ramp ; F, target.



The U.S. Navy's "Little Joe" anti-aircraft rocket. Canard type with straight wing and four fins.

inclination towards the beam, so that the rocket's speed component vertically to the beam direction precisely corresponds to the angular acceleration of the beam.

Generally speaking, the two guiding systems are not adequate to guarantee a collision between the guided missile and the target over any distance. In such cases the missile is equipped with an additional "target homing device" which takes charge of guiding the missile as soon as the latter has approached the target to within a given distance. In order to detonate the warhead, proximity fuses are mostly used, whilst an automatic self-detonating device provokes the explosion of misses.

In Germany a whole range of anti-aircraft guided missiles was developed during World War II. The best known, *Hs 117 "Schmetterling" ("Butterfly")*, had a small swept wing and was equipped with impulse guidance. Power was provided by a Walter or BMW bi-fuel rocket motor. Two booster rockets provided initial acceleration during the first few seconds of the missile's flight. The Henschel guided weapon, of which several versions were under development at the end of the war, was never used tactically. The same fate was reserved, incidentally, for all other German anti-aircraft guided missiles.

Rheinmetall simultaneously developed several types of anti-aircraft rockets: the "*Hecht*" and "*Feuerlilie*" ("Pike" and "Fire-lily"), the latter in versions designated F-25 and F-55 respectively, were small rocket missiles designed either for use with the command impulse or guide beam systems. "Hecht" and F-55 "Feuerlilie" had liquid fuel rockets, whereas F-25 "Feuerlilie" worked with solid fuel. All rockets were launched from inclined ramps.

A larger Rheinmetall guided missile was "*Rheintochter*" ("Rhine Daughter"), of which two versions, R-1 and R-3, were developed. It had a swept wing in six parts and a big booster rocket with four swept wings. The main motor of R-1 operated on solid fuel, that of R-3 on liquid fuel. The rockets were designed for control by command impulse.

Developed to the same specifications as the "Rheintochter" was type "*Wasserfall*" ("Waterfall"; cf. elsewhere in this issue), which was evolved from the range of A-4 (V-2) army rockets. Types "*Enzian*" and "*Rheinbote*" ("Gentian" and "Rhine Messenger") were both designed for sub-sonic speeds. "Enzian," which externally resembled the Me 163 rocket fighter, had a liquid fuel motor and took off with rocket assistance. The power plant of "Rheinbote" worked with solid fuel.

Towards the end of the war a guided anti-aircraft rocket was developed also in England, specifically for use against Japanese suicide attack aircraft. This was *Fairey's "Stooge,"* a rocket featuring a motor with solid fuel and four jettisonable booster rockets; it was shaped like a small conventional aircraft and equipped for command impulse control and visual sighting. The U.S. Air Force is at present conducting tests with the *Fairchild "Lark,"* a slender rocket with four straight wings arranged cross-wise and similarly cruciform tail unit. The power plant of the "Lark" operates on two liquid fuels; at the take-off the missile is first accelerated by powder rocket. In the first phase of its flight, the "Lark" is guided towards the target by the command impulse system, but in the subsequent phase a target homing device takes over.

In the Pacific an American anti-aircraft rocket went into service towards the end of the war. It was the U.S. Navy's *KAN-2 "Little Joe,"* and was a canard-type. It had four cruciform wings aft and cruciform fins forward. It carried a proximity fuse and was launched by booster rocket.

Another typical guided missile of this kind is the *Convair "Terrier"* of the U.S. Navy. The rocket has cruciform wings and is helped on its way by a long take-off rocket with cruciform stabilizing fins.

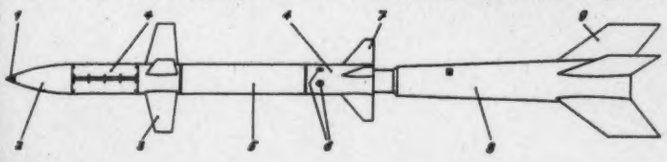
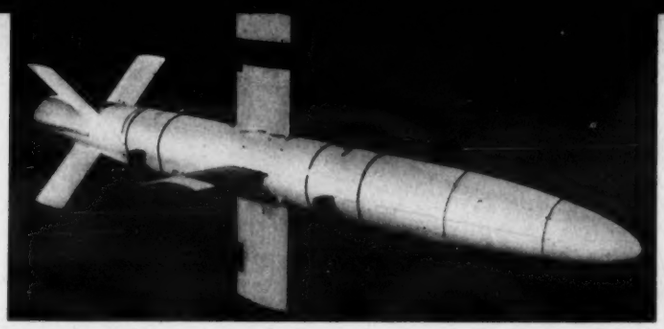
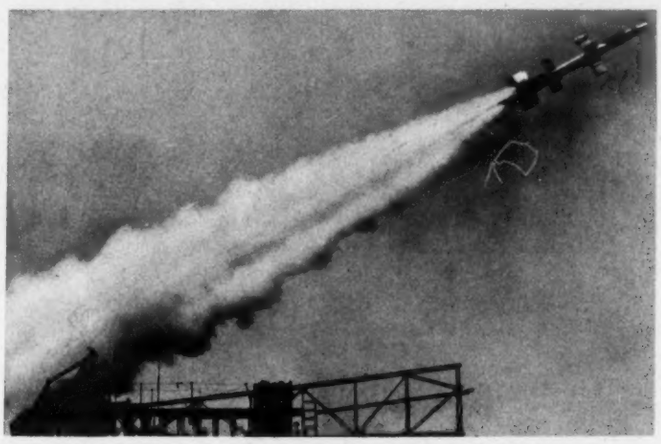


Diagram of the Convair "Terrier" naval anti-aircraft rocket developed jointly by Consolidated Vultee Aircraft and the Applied Physics Laboratory of Johns Hopkins University: 1 — fuse; 2 — warhead; 3 — missile wings; 4 — guidance and control sections; 5 — sustainer; 6 — electrical connections; 7 — missile tail fins; 8 — booster rocket; 9 — booster rocket fins.



The Fairchild "Lark" anti-aircraft rocket of the U.S. Air Force has straight cruciform wings and fins.



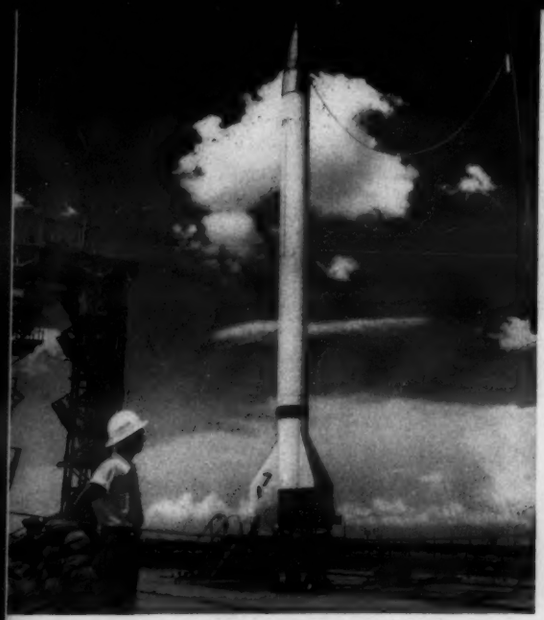
The Fairchild "Lark" is helped on its way by a large booster rocket.

Upon completing its combustion, the booster rocket drops away and the "Lark" continues alone with its liquid fuel motor.

Of the remaining anti-aircraft rockets mention should be made of the *Oerlikon guided rocket*, developed in Switzerland. It possesses a maximum speed of 2,460 ft/sec. and has a tactical range of 12½ miles. This aerodynamically cleanly designed rocket has four thin wing surfaces arranged cross-wise and is powered by a liquid fuel motor. The projectile is fired from a mobile launcher and is directed towards its target by a guide beam system. *rw.*

Guided Anti-Aircraft Missiles

Type	*Span in.*	*Length in.*	*Launching weight lbs.*	*Warhead lbs.*	*Fuel lbs.*	*Thrust duration secs.*	*Thrust lbs.*	*Top speed ft/sec.*
"Schmetterling"	73.2	157.5	990	55	165 176	60 4	838-132 7,716	980
Hecht	35.4	78.7	310	—	—	25	130	920
"Feuerlilie" F-25	35.4	49.2	265	—	37	6	1,100	720
"Feuerlilie" F-55	98.4	188.9	1,040	—	309	25	2,200	1,345
"Rheintochter" R-1	86.6	224.4	3,860	243	529 485	0.6 2.5	165,340 35,274	1,640
"Rheintochter" R-3	—	185.0	2,150	—	—	0.9	30,870	—
"Wasserfall"	98.8	309.1	7,720	—	4,286	4.2	17,640	2,165
"Enzian"	393.7	381.9	4,340	—	1,323	7.0	4400-2200	820
"Rheinbote"	—	263.2	3,360	1,102	—	—	—	799
"Little Joe"	—	—	—	100	—	—	—	590
"Stooge"	81.8	89.3	740	—	—	1.6	5,510	—
"Lark"	—	177.2	1,210	—	—	—	—	—
Oerlikon	—	—	550	—	—	6.0	—	2,460



August 7th, 1951: The U.S. Navy's No. 7 Martin "Viking" rocket, tilted 3 degrees to the North, stands on its launching platform at the Army White Sands Proving Ground, Las Cruces, New Mexico.

Installation of intricate electrical wiring in the "Viking" requires hours of painstaking labour. The maze of controls must be adjusted with utmost precision to ensure that the hundreds of electrical circuits throughout the rocket function properly, in order to produce a perfect take-off.

Rocket Away!

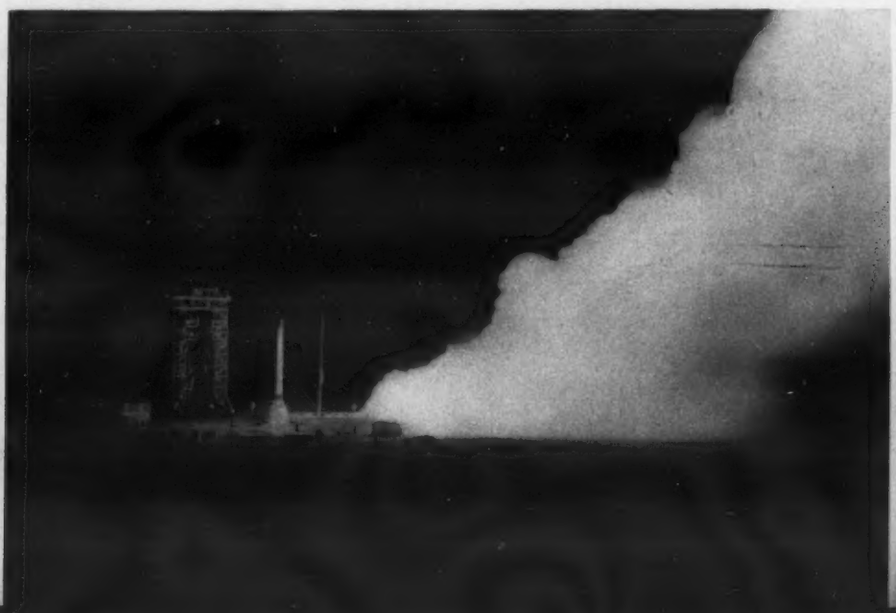
On August 7th a "Viking" high-altitude research rocket built for the U.S. Navy by The Glenn L. Martin Co., of Baltimore, Md., well-known aircraft manufacturers, roared away from the U.S. Army's White Sands Proving Ground at Las Cruces, New Mexico, to an altitude of 135 miles, attaining a top speed of 4,100 miles an hour. Its rocket engine burned for 75 seconds after take-off, and in that time the missile reached an altitude of 25 miles. After that it coasted the rest of the way and got to its maximum height in 4 minutes 23 seconds. It was still travelling very fast when it hit the earth.

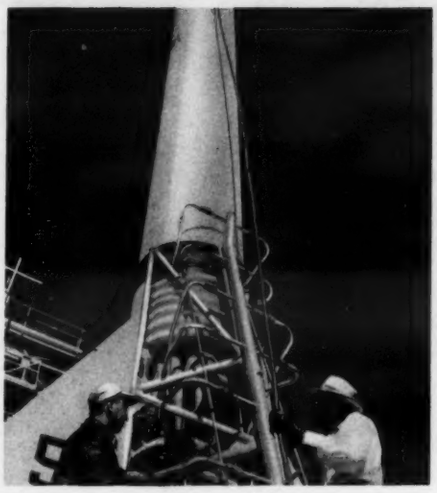
Rockets have been shot to heights of 250 miles in experiments at United States testing grounds, but such altitudes have been reached by two-stage missiles. Never before had a single-stage rocket attained anything like 135 miles: the previous record had been held since 1946 by a captured German V-2 "reprisal" rocket fired in the U.S.A., which

Scientific equipment in the "Viking," which records and broadcasts upper-atmosphere information back to earth, is carefully checked. The scientific apparatus, located in the rocket's nose, is automatically ejected forty miles above the earth during the rocket's fall and floats down on ribbon parachutes.

The "Viking" rocket at the Glenn L. Martin factory, Baltimore, Md. Electrical, hydraulic and fuel systems are checked on the factory floor. The rocket is then broken up into three sections—nose, belly and fin—to be transported by railroad flatcar to White Sands. Rails lead right into the rocket hangar, where the flatcars are then pushed together to join the rocket pieces.

The "Viking's" engine is tested before actual firing. The rocket is bolted to its launching platform to prevent it from taking off. The exhaust flames escape into a water-filled pit and create steam. At night they illuminate the area for miles.





Firing day: activity begins around the launching site long before dawn. Ten tons of ethyl alcohol are pumped into the fuel tanks three hours before firing time. Electrical circuits are warmed up by outside power, since rocket batteries are connected only a few seconds before take-off.

rose to 114 miles. The Navy hopes that ultimately the "Viking" will reach a height of 235 miles and a speed in excess of 6,000 m.p.h.

The Navy originally ordered 10 "Viking" rockets, but this number may have been increased. The first rocket was launched at White Sands on May 3rd, 1949. It attained an altitude of 51.5 miles and a maximum speed of 2,250 m.p.h. The second was fired on August 25th of the same year, but it merely sat on its tail platform emitting fumes, despite repeated punching of the motor starting button in the nearby control building: a leak in the liquid oxygen system apparently froze the starting valves. Twelve days later, on September 6th, 1949, it rose to an altitude of only 33 miles, after coasting upward for the last 22 miles following an unexplained motor cut-off.

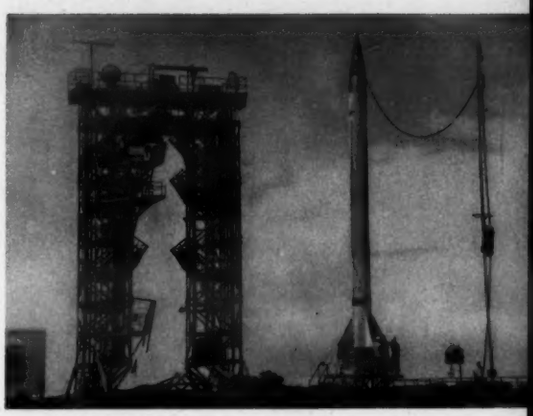
Navy technicians were not disheartened by these mishaps. They simply regarded them as the result of motor control "bugs" which failed to appear in static tests and had to be worked out gradually. Their patience has been rewarded, for five more rockets have since been launched successfully, including the record-breaker and another from the deck of a U.S. naval vessel.

Equipped with a liquid rocket motor built by Reaction Motors Inc., the "Viking" develops a thrust of about 50,000 lbs. The propellant is alcohol and liquid oxygen. Overall length is 45 ft., span across the fins 98 ins. and gross weight 11,000 lbs. During one test the missile carried a 900-lb. load of scientific equipment to a height of 106.4 miles. Radio instruments broadcast back to earth such information as altitude, temperature and cosmic ray count.

The "Viking" is purely a research rocket. It helps to provide the technical knowledge necessary for the development of guided missiles of tremendous power. Various forms of missile will serve as anti-aircraft weapons, or as weapons intercepting and detonating enemy missiles before they reach their targets, and also as weapons of long-range attack—as visualized by the German engineers who created the V-2 during World War II. Development is slow, however: while the Germans had evolved a 114-mile rocket by the end of the war, it has taken U.S. engineers six years to increase this altitude by 21 miles! This difficult evolution seems to have persuaded military engineers of the near-insurmountable problems of *rocket-powered* missiles for long ranges, and both Glenn L. Martin and another U.S. manufacturer, Northrop Aircraft, are now developing 5,000-mile range missiles—swept-wing pilotless aircraft—*powered by conventional turbojet engines* and flying at about 600 m.p.h. Last July the USAF fired its first longrange missile, a Martin "Matador" at Patrick Air Force Base. Other tests will follow shortly.

Thus the "Viking" experiments, together with tests made with missiles built by other manufacturers (Aerojet "Aerobee," Ryan "Firebird," Convair "Terrier," Boeing GAPA, etc.), form part of unceasing efforts by the U.S. armed forces to acquire new knowledge in the missile field for defence and offence. How exciting this new "science" appears to the man in the street is evident from the fantastic speculations which circulate all over the world about the forthcoming development of outer-space guided missiles of intercontinental range, armed with atomic warheads. Warheads? We hope they can be replaced with compartments carrying "missile mail" from continent to continent within the space of minutes or hours.

No. 7 "Viking" receives a final check by several technicians on the morning of August 7th.



The "Viking" ready to go. The gantry or working platform on the left is used to set up the rocket on its launching table and prepare it for take-off.

The record-breaking No. 7 "Viking" of the U.S. Navy takes off in a burst of thundering noise, spouting brilliant whitish-orange flame from its tail. Pausing for a split second a few feet above the ground, the rocket rises slowly at first, then gains the tremendous speed that will send it more than 135 miles into the sky. In 75 seconds, and at a height of 25 miles, all fuel will be consumed, and the rocket will complete its flight by momentum.

All that is left of the slender missile. Radar sets locate the area of the crash and the landing point of scientific equipment. In right foreground is part of the rocket's thrust cylinder.

Peenemünde's Super-Sonic Wind Tunnel

BY DR. WERNER KRAUS, GRENZACH IN BADEN

Of late, more and more reports have been appearing in the press on supersonic rockets and other high-speed projectiles. Some of these are objective reports, others sensational stories. Nearly all deal with military projects. Yet it should not be forgotten that high speed aerodynamics are also becoming more and more important in civil aviation.

Commercial aviation's efforts to reduce distances by increasing speed, investigation of the upper air levels by means of measuring rockets, and present-day work by astronautical enthusiasts in the direction of space travel, are also examples of this.

Supersonic aerodynamics—and the more advanced "aerodynamics of highly-diluted gases"—will doubtless become increasingly important in technical aeronautical progress during the coming decades. The following is an account of some of the methods of research into basic principles which were used at Peenemünde up to the beginning of 1945.

How a wind tunnel works

What are the flow and thermodynamic phenomena connected with the high-speed flow of air? Such questions can frequently only be answered by systematic experiments. In actual flight conditions the body moves and the air remains stationary—leaving aside the effect of wind. Investigations into flow processes round an existing aircraft can of course be made in free flight. However, such investigations require complicated and costly measuring equipment and the results obtained are often meagre and not over-reliable. In cases where new aerodynamic forms have to be developed it is obviously better to carry out the necessary experiments on models.

These models are set up on balances and other measuring equipment in a wind tunnel, and air is blown on to them. The measurements made on the models—forces, moments, pressures, temperatures, etc.— are only true to life, *i.e.* they can only give a reliable picture of the conditions obtaining in free flight, if the laws of "physical similarity" are observed. The models must therefore be true scale miniatures of the actual machine and have an exactly similar surface; the relationship of the forces of inertia in the air flow round the body to the friction forces in its boundary layer must be approximately the same for the model and for the body in free flight (Reynolds number). Finally, the relationship between the speed of flow and that of sound (depending on the absolute temperature of the moving gas), *i.e.* the Mach number, is also important at high speeds.

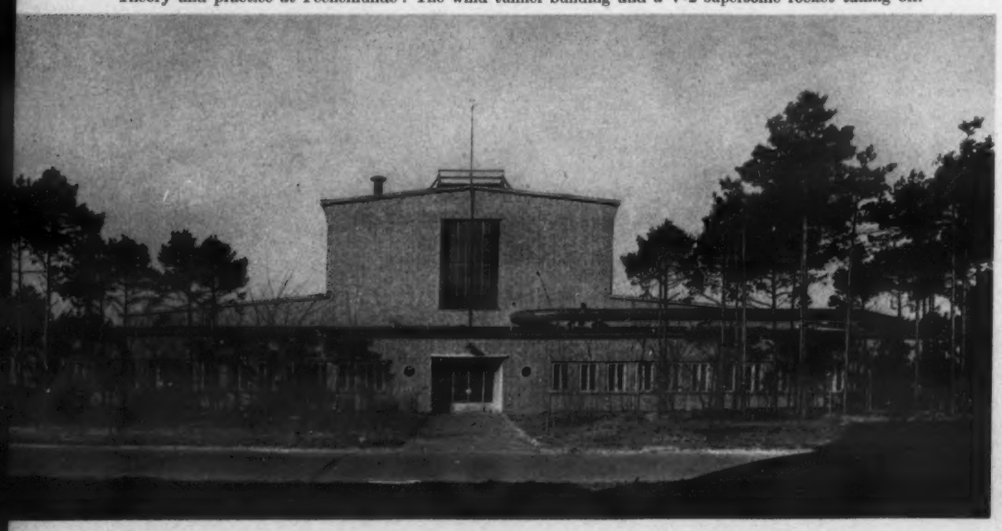
Another important point is that the air flow in the wind tunnel must be extremely regular. An exactly parallel flow of constant speed is required. Even then corrections generally have to be made when evaluating the results, *e.g.* allowance made for the limiting effect of the fixed walls of the tunnel on the flow (compared with the free atmosphere).

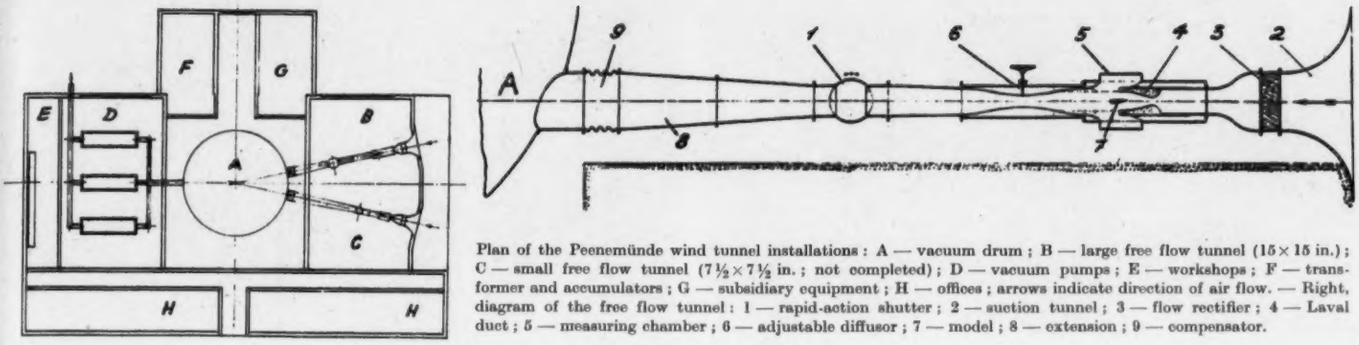
Types of wind tunnels

There are today a great number of wind tunnels for medium speeds, *i.e.* up to approx. 180 ft/sec. Some of these work with an airstream several yards in diameter. At higher speeds compressibility becomes noticeable. At over 450 ft/sec. it begins to play a decisive part, and air flows from this speed up to the speed of sound are known as "compressible subsonic flows." Beyond the speed of sound lies the region of "supersonic flow."

Consequently wind tunnels can be divided into three kinds:— 1) purely subsonic tunnels; 2) tunnels for compressible subsonic

Theory and practice at Peenemünde: The wind tunnel building and a V-2 supersonic rocket taking off.





Plan of the Peenemünde wind tunnel installations : A — vacuum drum ; B — large free flow tunnel (15 × 15 in.) ; C — small free flow tunnel (7½ × 7½ in. ; not completed) ; D — vacuum pumps ; E — workshops ; F — transformer and accumulators ; G — subsidiary equipment ; H — offices ; arrows indicate direction of air flow. — Right, diagram of the free flow tunnel : 1 — rapid-action shutter ; 2 — suction tunnel ; 3 — flow rectifier ; 4 — Laval duct ; 5 — measuring chamber ; 6 — adjustable diffusor ; 7 — model ; 8 — extension ; 9 — compensator.

flows; 3) supersonic tunnels. A distinction is also made between *closed circuit tunnels* and *open tunnels*.

In the first type air is sent round a continuous circuit by means of a nozzle, so that the same air is used all the time. Consequently it needs filtering only once. Also, other gases (other than normal air) can be used, a valuable feature in view of the fact that the composition of the atmosphere varies with the altitude of flight. In the open type fresh air is taken in from the atmosphere by means of a vacuum pump, passed through the tunnel and blown out into the atmosphere again.

A decisive factor in planning a wind tunnel installation is the blower power available. In supersonic tunnels the power required for continuous operation is very high, increasing as the cube of the speed. In a wind tunnel with a flow section 15 × 15 in. it would take roughly 4000 kW (*i.e.* 5000 h.p.) to produce the Mach number 4, *i.e.* four times the speed of sound. Power also depends of course on the type of flow used and on the technical design of the tunnel.

In cases where available resources have to be used as economically as possible the "*open tunnel with intermittent operation*" proposed by Professor Prandtl can be used. This uses a vacuum drum to store up energy, so that the blower need only be powerful enough to empty the drum within a reasonable time. The open tunnel, however, has the disadvantage that no other type of gas but air can be used and that this air must constantly be filtered to rid it of dust, moisture, etc.

Regardless of the type of tunnel, various different types of stream can be used, such as fully controlled stream, semi-controlled stream, free stream, according to whether the walls of the tunnel enclose the air flow completely, partially or not at all.

The Peenemünde installations

The supersonic wind tunnel at Peenemünde's aerodynamic section was an *open free-flow tunnel for intermittent operation*. The plan of the installation shows it to have been divided into three parts. In the centre there was the vacuum drum, on the right the test chambers with measuring areas and on the left the machine room with vacuum pumps. There were also subsidiary rooms, workshops, offices, etc.

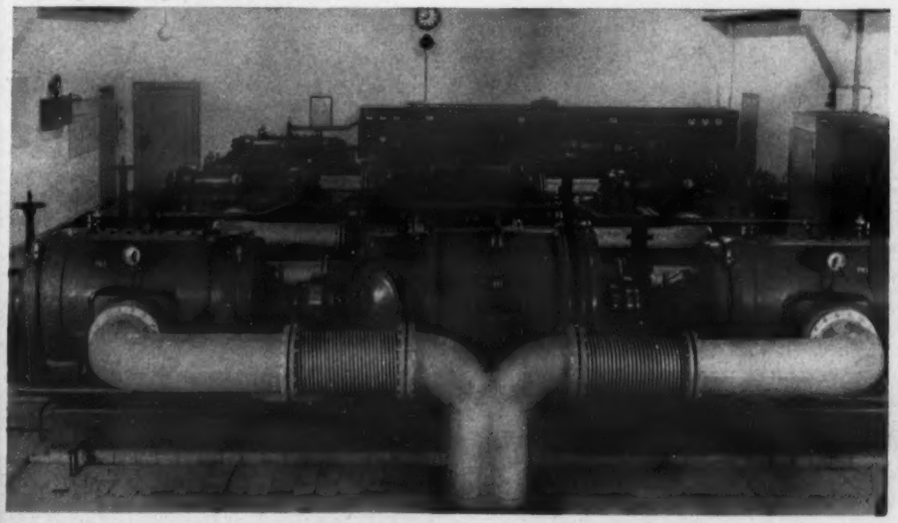
Another plan shows how the two measuring chambers worked. A rapid-action shutter closes off the measuring area from the vacuum drum so that the suction pumps can evacuate the drum. As soon as the pressure in the drum is low enough for the required speed and duration of flow the shutter is opened and the outside air flows (from the right) through the suction funnel, rectifier and Laval duct into the measuring chamber. From here it passes via an adjustable diffusor into the vacuum drum. A few seconds later the shutter closes off the measuring chamber again so that the vacuum pumps can once more empty the drum.

It took 3 to 5 minutes to empty the drum, and the "flow duration" for one measurement was an average of 15 seconds. Consequently all equipment had to be devised so that satisfactory measurements could be made within the 15 seconds available.

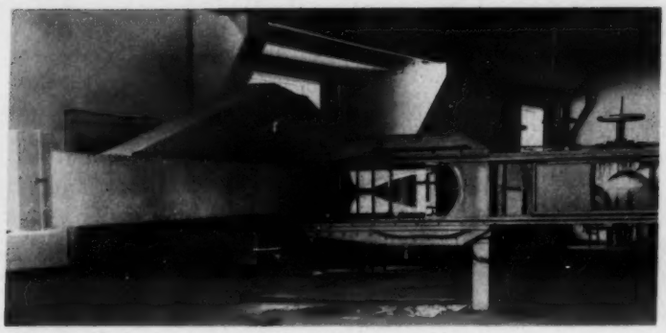
The suction funnel had an aperture of 160 sq.ft. To avoid the formation of eddies and prevent the entrance of foreign bodies, the air was passed at low speed through a rectifier consisting of a number of tubes, which largely eliminated cross movements.

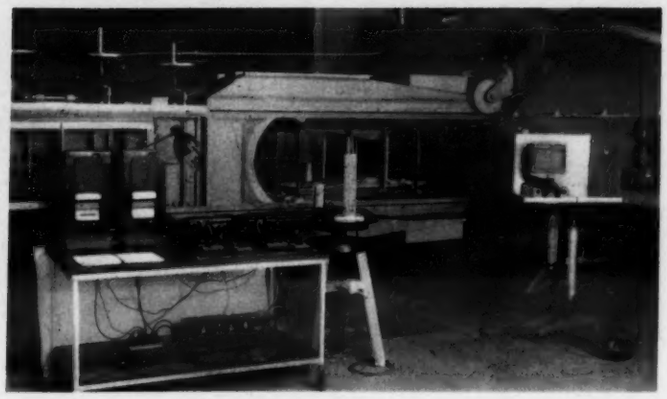
At the entrance to the measuring chamber the Laval duct, whose design for any given supersonic speed was determined according to a method worked out by Prandtl and Busemann, converted the heat-energy content of the air into kinetic energy, and produced speeds of

The wind tunnel's machine room had three electrical pump systems which were connected in parallel or in series according to the degree of vacuum in the drum.



External view of the air drying filter, which uses silica-gel.





View of the measuring chamber (from both sides) with various Laval ducts. The chamber is open ; three spindles and an electro motor (not visible here) control the diffusor. The mobile stria camera can be seen alongside the measuring run ; front right, a temperature recorder.

flow of up to about 4600 ft/sec. [1] The square-sectioned supersonic stream had a side up to 15 in. long and ducts were available for Mach numbers 1.22, 1.56, 1.86, 2.5, 3.3, 4.4.

The measuring chamber contained the aerodynamic three-component balance for measuring lift, drag and moment of the model. This was a spring band balance (without complicated mechanical parts) with electrical remote reading and an accurarcy of 1%. The balance was fitted in a pressure-tight chamber and screened from disturbing influences in the airstream. The angle of incidence of the models in relation to the flow could be automatically adjusted during tests.

Measuring chamber and Laval duct had thick sheets of glass at the sides, through which the flow processes could be watched by means of a stria apparatus. The glass, needless to say, must be of high quality.

The adjustable diffusor behind the measuring chamber consisted of two flexible steel sheets, which could be adjusted by mechanically-operated spindles to alter the delivery section of the airstream behind the measuring chamber at will. The object of the diffusor was to maintain the correct pressure in the measuring chamber after the build-up of the supersonic flow, and to sustain the speed of flow as the vacuum drum became filled with air.

Towards the end of the tunnel it changes from a square into a circle of greater diameter, the kinetic energy now being converted into pressure. The final portion, connecting the tunnel to the vacuum drum, was in the form of a compensator to allow for changes in the length of the measuring distance.

The capacity of the vacuum drum, determined not only by the flow section but also by the minimum flow duration required, was 35,300

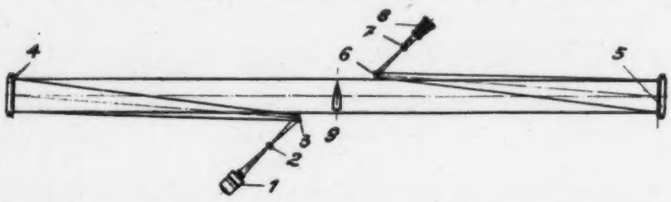
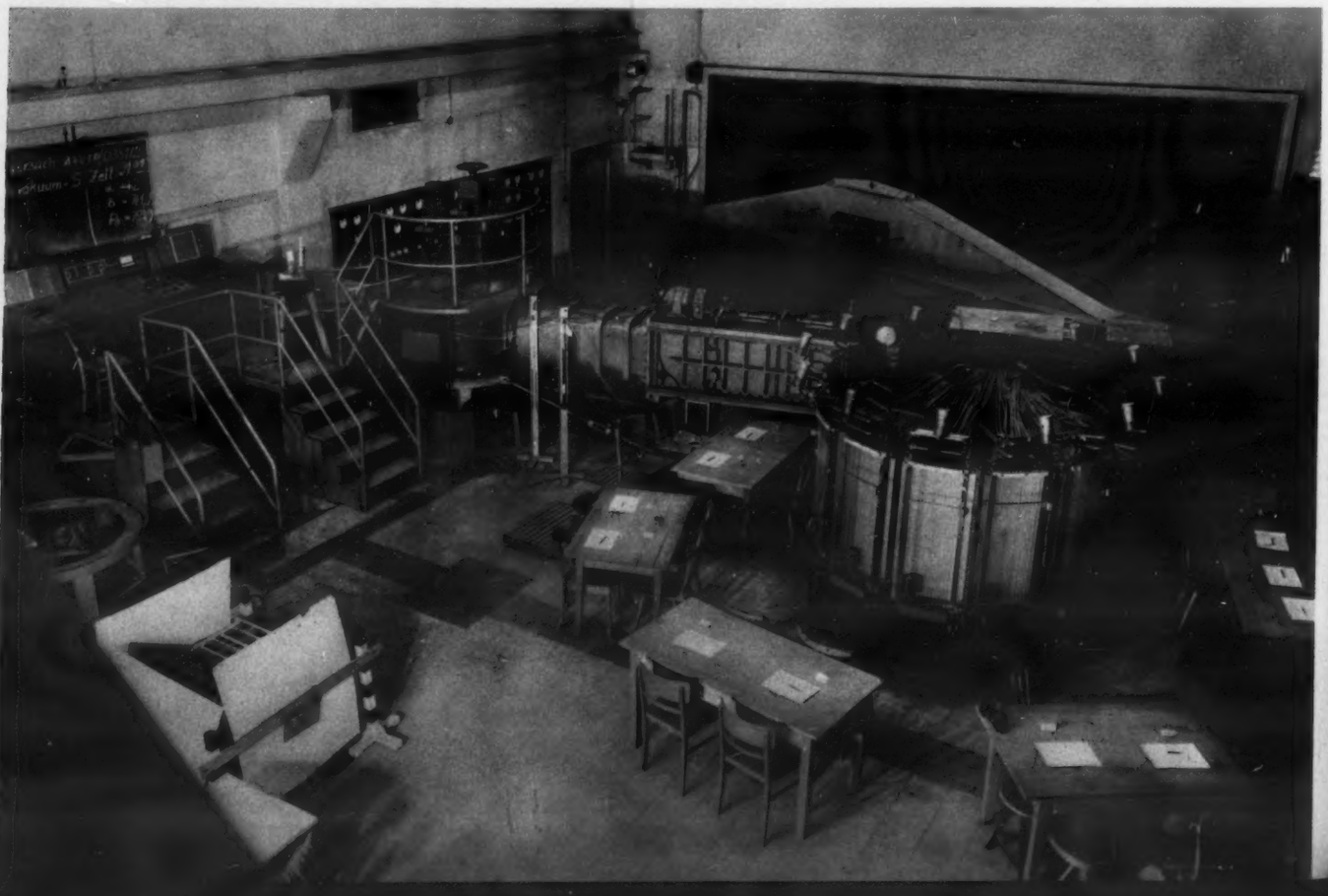
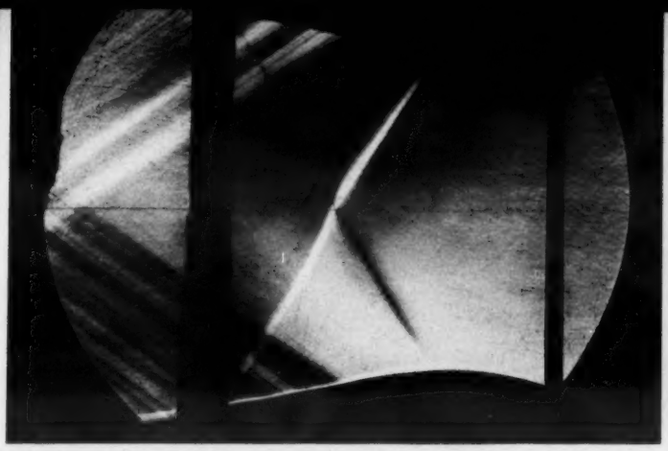


Diagram of the stria apparatus : 1 — arc lamp ; 2 — slot ; 3 — plane mirror ; 4, 5 — concave mirrors 20 ins. in diameter, focal length 16 ft. 4 ins. ; 6 — plane mirror ; 7 — stria shutter ; 8 — matt screen or camera ; 9 — model.

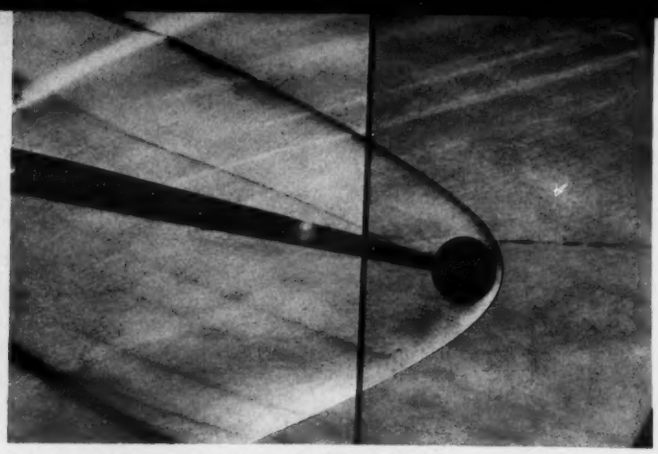
[1] The Laval duct has its narrowest section near the entrance and an appropriately wide section downstream. The relationship between the two sections determines the supersonic speed that can be obtained by the duct. Since no heat is added or removed a so-called "adiabatic" expansion takes place.

View of the research premises, with wind tunnel and control desk. A cylindrical multiple manometer is used for measuring pressure distribution. The 30-ft. stria camera can be seen in the background.





Stria photo of a condensation thrust emanating from the narrowest section of the Laval duct as a result of excessive moisture in the air : Mach number 1.86.



Stria photo of flow round a sphere : Mach number 3.25.

cu.ft. The drum was spherical, of stiffened metal sheet 11/16 in. thick, joined by 13,000 rivets. During pressure tests only two rivets were found to be leaky.

The pump system could produce a 99% vacuum in the drum in five minutes. It consisted of three units, each containing two Demag pumps with a common motor. Up to a vacuum of 90% these units ran in a single stage in parallel; from 90 to 99% two units ran in parallel (as first stage) and the third in series (as second stage). The power required to drive the whole system was 810 kW or 1100 h.p. During the tests it was found that an air delivery volume of 1,172,450 cu.ft/hr. for a 60% vacuum and 766,300 cu.ft/hr. for a 90% vacuum was required. The pumps were mounted on shock absorbers to prevent oscillations being transmitted to the measuring chamber. Needless to say the foundations of the measuring chamber were also carefully designed.

It is not possible here to describe the many accessories, such as pipes, valves, filters, etc. and above all the extensive electrical remote control equipment. However, a word on the hemi-spherical dry filter in front of the suction funnel will not be out of place. Its 12-in. filter pad was composed of silica-gel, a silicic acid product, and was capable of absorbing practically all the moisture from air passing through it at a speed of approximately 1.6 ft/sec., *i.e.*, reducing it from 12 gr. water vapour per kilogram of dry air to 0.2-0.5 gr/kg. The filter pad weighed roughly 15,430 lbs.

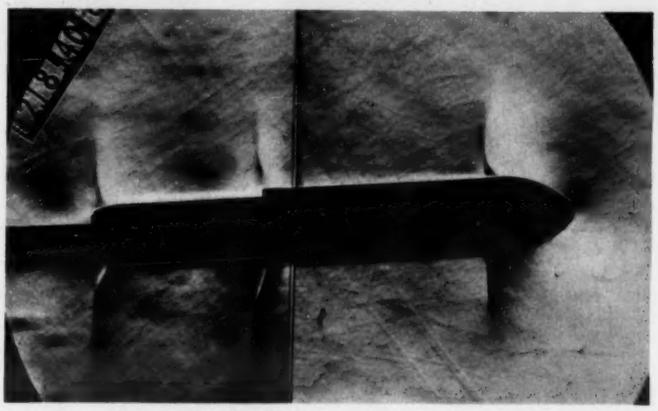
When saturated the filter pad was dried by means of hot air and was then ready for use again. In addition, a cold air stream prepared in a special drying plant played on the filter during the pauses in operation of the tunnel, *i.e.* while the vacuum drum was being pumped out.

Thorough drying of the airstream was found to be essential, as otherwise condensation disturbances (resulting from expansion and cooling of the air in the Laval duct, cf. picture) were encountered, which made reliable measurements impossible.

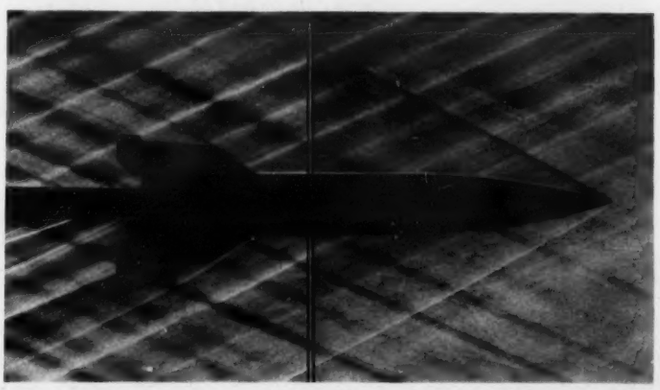
The stria (Schlieren) optical device

The wind tunnel's measuring equipment included an optical device for observing air flow by Toepler's stria method, a 30-ft. long apparatus whose operation is illustrated in the accompanying diagram. The local variations in density in the air flow are observed on a sheet of ground glass with the aid of a camera. The light beam from an arc lamp, in conjunction with the lens system, which is composed of plane mirrors, concave mirrors and a so-called "stria (Schlieren) shutter," showed up the varying air densities of the flow round the model in the form of light and dark patches.

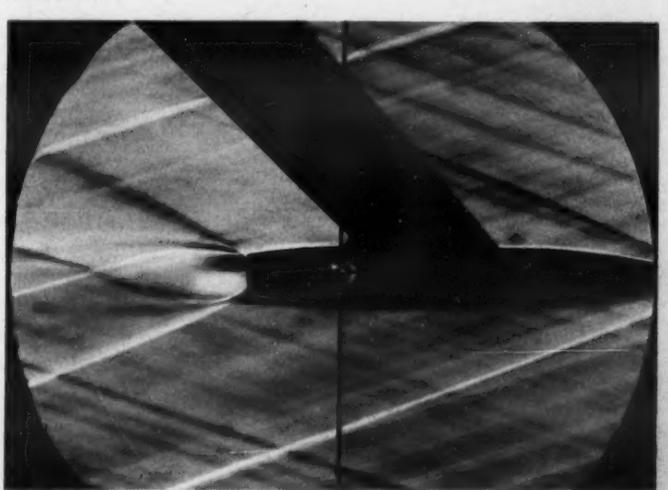
Examples of stria photos of various models in the subsonic and supersonic range are shown in the accompanying pictures. In the picture of the shell in an airstream with a speed of 0.95 times that of sound the formation of local supersonic regions and accompanying compression disturbances are clearly recognizable. In the pictures of models subjected to supersonic flow the most striking features are the Mach cones formed at the tip, comparable with a ship's bow wave. The photographs have been taken from the archives of the Aerodynamic Institute of Peenemünde Research Centre.



Stria photo of flow round a shell in the "compressible subsonic range" : local supersonic flow ; Mach number 0.95.



Stria photo of flow round a model of the V-2 rocket : angle of inclination 0° ; Mach number 2.47.



Stria photo of flow round a tailless rocket, the propulsive jet being simulated by compressed air : Mach number 3.25.

Fair Wind over the Wasserkuppe

First Rhön Rally since the War

Roughly twelve months ago the German Aero Club was revived in the little town of Gersfeld at the foot of the Wasserkuppe in the Rhön district, the "sacred mountain" of German gliding. This event was welcomed not only by German gliding enthusiasts but also by their foreign colleagues and scientists who were eager to see German youth re-admitted to a sport which they had pursued for its own sake—leaving aside the Hitler epoch—over many years.

A year later, on August 25th and 26th, 1951, the first glider meeting took place on the Wasserkuppe. This first rally was notable not so much for the quality of its gliding as for the attempt to recreate the old tradition. Thousands of people had flocked to the Rhön from all parts of Germany, and from Austria, Switzerland, the USA, Great Britain and France. Roads were jammed, and even the most modest hostelries for miles around were full to overflowing. Beer tents and sausage stalls gave the whole a festive air.

The actual sporting event was perhaps less spectacular. In 1937 a total of 28 gliders from seven different countries met for the International Rhön Contests. By 1939 the number had risen to 60. But in 1951 a modest start was made with 12 gliders, five of them registered abroad.

Nearly all the gliders were two-seaters of old design. The *new designs* included the *ES 49 two-seater* of Alexander Schleicher, who had taken up furniture manufacture at Poppenhausen (on the Wasserkuppe) after the war, but had now returned to glider construction. He builds the old Grunau Baby for about DM 5,500, and is also engaged on a model of his own, which was developed by Edmund Schneider. Another new design was the "*Doppelraab*" designed by Fritz Raab of Munich, a two-seater glider trainer built by the Dachau section of the Aero Club. Wolf Hirth, well-known former gliding pioneer and now President of the Aero Club, has gone back to his design work; however his "*Gö IV*" was not ready for the Wasserkuppe this time. The 20-ft. span tailless glider designed by Werner Lutz, of Giessen, was also missing, since it had been damaged at a little place called Hirzenhain, on its way to the Wasserkuppe. Yet another new design was the "*Bergfalke*," a high-wing glider with steel tube fuselage, built by the unemployed of the Watenstedt-Salzgitter district (where British dismantling at one time aroused so much discussion).

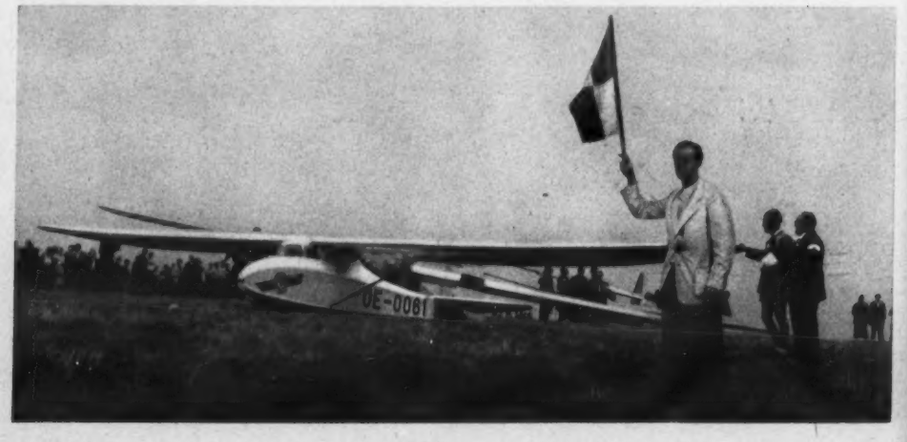
Actually very little flying was done. The Wasserkuppe is only about six miles from the Russian Zone, and lengthy flights had to be forbidden, since they might so easily have led to complications. Only a few Americans and British therefore made use of the up-currents.

The personalities attending the rally included, of course, Wolf Hirth, as President of the Aero Club, and his staff, in particular Fritz Stamer, the active secretary-general. There were also RAF cadets, American officers and Austrian glider pilots. It almost seemed as if the latter would not be able to fly, since their insurance policies did not cover flights outside Austria. However, their German colleagues got together and paid the premium for them. The Aero Club can no longer call on the ample funds which existed during the National Socialist régime, but must work with much more slender resources. The rally was also attended by Oskar Ursinus, the "Father of the Rhön" and the indomitable Hanna Reitsch. Finally, there was the Frenchman Guy Marchand, holder of the world endurance record and a true European, who has worked untiringly for the renaissance of German gliding.

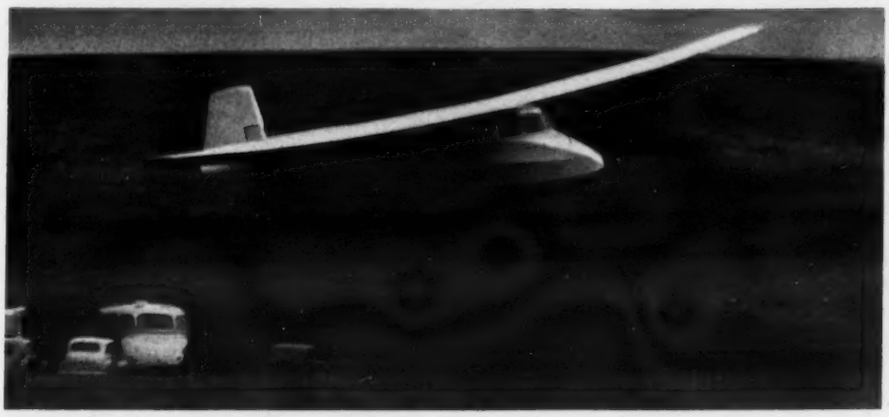
Here is the whole picture. It is modest enough, and in truth represents only a beginning. The old Rhön spirit may still be alive—and we leave it open whether the word "still" is to be used in optimistic or pessimistic sense. It will live in the enthusiasm of a new generation of German youth which has been able to free itself from the militaristic tendencies which Hitler and his armament fever brought to gliding before the war. It will certainly live if Wolf Hirth is given a free hand. His opinion is that the problem of building gliders will be easier to solve than that of training the pilots. Thus—quite apart from the financial difficulties—there will be limits to the number of gliders built. The fact that it is no longer possible in the narrow territory of Western Germany to make long flights complicates training and the holding of contests. The latter will have to be restricted to flights to a predetermined point or on a triangular course. There is some talk at present of Germany taking part in the 1952 Olympic Games, but no decision will be made until it is seen how the new gliding generation shapes and how it shows up in next year's Spanish International Championships. Wolf Hirth estimates that training will cost about DM 100,000, a considerable sum for German gliding to find today.

Women have to come into it somewhere . . . Mrs. Uschi Kanngiesser, of Gersfeld, at the controls of the SG 38 training glider.

An Austrian pilot in his "Grunau-Baby."



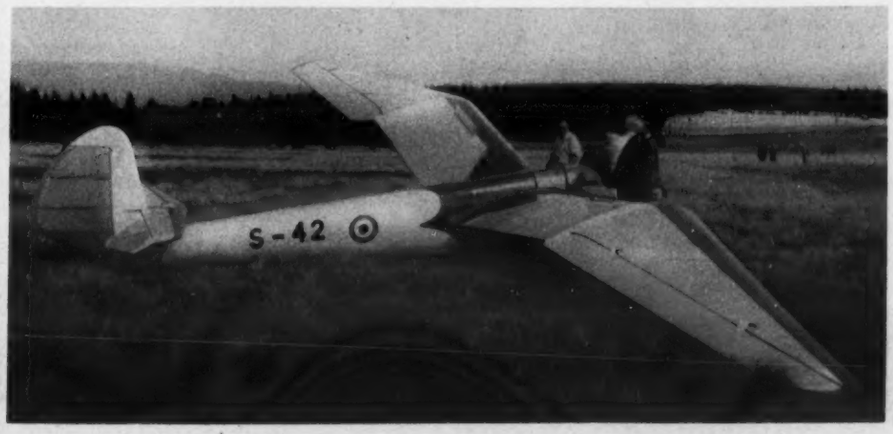
The British with their "Kranich"... made in Germany.



The "Cumulus," a new design, with steel tube fuselage.

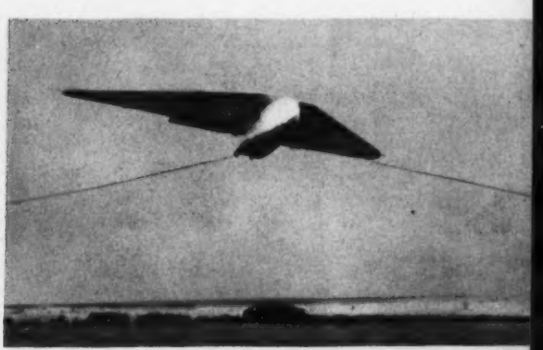
A "Mü 13 E" of the Munich students' flying group being prepared for winch take-off.

The "Minimoa" of the French Air Force, an earlier design by Wolf Hirth, now President of the German Aero Club.



A word on the general development of this sport, in which German youth did valuable pioneer work in the old days. About the middle of August "Die Welt," a responsible Hamburg newspaper, published an article entitled: "Hands off! Gliding enthusiasts need help but not patronage." The question was raised of who should "take care" of the new German gliding, the Federal Ministry of Transport which will be in charge of future civil aviation, or the Federal Ministry of the Interior which is responsible for all other branches of sport? It was stressed that gliding is a sport like gymnastics or rowing, and that, for example, sailing and rowing enthusiasts are not subject to control by the Shipping Department of the Ministry of Transport. Why, it was therefore asked, should gliding not also come under the Ministry of the Interior? The German Aero Club was ready with its answer. There should be no doubt whatsoever, it stressed, about the purely sporting objects of gliding. But the peculiar hazards of this type of sport required a strict, officially controlled organization. The appropriate authority would be a future Air Department of the Federal Ministry of Transport, with whom, as with the Ministry of the Interior, the Aero Club enjoyed cordial relations.

The Aero Club is right. It is right in calling attention to the peculiarities of the



The tailless design of Werner Lutz, Giessen, which was damaged before the meeting.

sport it represents, since the whole question of the "air space" is a ticklish one. However, the question raised by the article in "Die Welt" cannot altogether be passed over in silence. Today the call is to train German gliding in the old spirit which reigned in the Rhön between 1919 and 1932. This was its greatest period, and it was then that—without uniforms—it called forth the admiration of the world. The misgivings of the writer of the article become readily understandable if the representative of the Federal Ministry of Transport who is to be responsible for this sport in future is to be an ex-Luftwaffe general and holder of the Nazi "Blood Order."

Second International Swiss Air Rally

BY CAPTAIN HERMANN SCHREIBER, WINTERTHUR

The Second International Swiss Air Rally for sports and touring aircraft took place from August 11th to 16th. Twenty-nine aircraft from Belgium, Denmark, Great Britain, France, Holland, Italy, Luxembourg, Persia, Spain, Yugoslavia and Switzerland took part in this tour of Switzerland.

Marcel Doret, the French veteran pilot, flew his "Norécrin" through many an air pocket.

The object of the rally was to familiarize Switzerland's foreign guests with the problems of air navigation over mountainous country. A number of navigation problems were set during flight and a precision landing contest demonstrated afresh that to be able to fly one must be able to land. The chairman of the Organizing Committee was Dr. Markus Burkhard, Deputy Director of the Swiss Federal Air Office, who himself took part in the rally. Major Liardon was in charge of the flight arrangements.

Not only all the usual sports and touring aircraft, from the "Piper" to the "Navion," were lined up for the take-off, but also several veterans, such as the Messerschmitt "Taifun" and Bücker "Bestmann" lent by the Swiss Air Force. The "Taifun," although 15 years old, soon proved to be equal to today's touring aircraft. This is a good testimonial for the aircraft; it should also arouse the designers of this class of aircraft from their slumbers.

The whole rally went off without a hitch and may perhaps be repeated in 1952.

Saanen-Gstaad, in the Swiss Alps, sheltered pilots of powered aircraft and gliders, model builders and veteran balloonists.

Frock to Bant?

The controversy over the question of whether rearward-facing seats should be installed in transport aeroplanes still rages over the aviation world and has become as popular a subject for discussion as "Which came first, the chicken or the egg?"

We should make it clear that we are on the side which advocates leaving things as they are, namely, front to front. We have found, on flying in a Handley Page "Hastings" transport fitted with the back-to-front arrangement, that with the seat belts attached we were in danger of being cut in half in a steep climb and, without belts, of rolling down the cabin into the tail.

We, being human, are averse to being told how and where to sit even when it is allegedly being done for our own good. Besides, having flown in airliners in various parts of the world, we consider that we and our nearest and dearest have an excellent chance of arriving at our destinations and that airline people are leaving no spanner unturned in increasing our survivability even further.

We have conducted some research and have found the opponents of the back-to-front idea are, in the main, people who fly a great deal for business or pleasure and who actually take their mode of transport and its existing form for granted. They only show signs of petulance on finding that the other passenger is becoming knowledgeable enough to grab the back seat. On this point, however, it is not yet known whether their choice is governed by proximity to the exit in the event of a crash, or to the lower noise level, or to the fact that the hostess usually sits there when she has a moment to spare.

Those in favour of this revolutionary modification appear to be people who do not habitually fly in airliners but who, to judge from their statements, apply to the problem all their experience of military flying with loaded bomb-bays and the exhilaration of circuits and bumps with some of the more sporting types of aircraft and pilots.

Of the two opposing forces the protagonists of the idea are certainly the most articulate and vehement. They quote many harrowing examples from the files of the accident reports which they have suitably edited to prove their case; and, in their opinion, the airline official has become a creature of horn and hoof who cares not how much blood is spilt so long as his costs do not increase.

Not only would they have us sit with our backs to the engines but think it necessary that we wear life-jackets and parachutes; they say that an oxygen point must be within reach for use when the pressurization fails even if all else should by some chance go well. An old aviation journalist has been heard to favour repositioned chairs and, in addition, has suggested that a mirror should be placed on the back of the seat in front, which is really the front of the seat in back, so that one could see a reflection of where one was going.

The point of view of the pilot should also be taken into account, since we cannot as yet get along without him. It might be worth recording in this connection that Santos-Dumont, making the first aeroplane flight in Europe in 1906, had a backward facing stand but did not, at that time, appear to realize the significance of this and consequently made his historic flight tail first.

We would like to read the reports of any airline which has instituted some inquiries into this matter as an indication of the passengers' inclinations. For instance it would be of interest to know in which direction the Eastern potentate sat who recently bought two tickets—one for himself and one for his feet.

We know of one passenger who was occupying a backward facing seat on a flying-boat which had, although we hate to admit it, an alighting accident. The back of the adjustable seat went into its fully reclined position and the passenger was shot out head first backwards, which was forwards, through his seat-belt. And where did that get him?

Having written this clarification of the problem, we are now lying flat on the floor, face downwards, which is upwards in the Southern Hemisphere.

Cassiopeia.

What's in the Air? *

MUCH ADO ABOUT COMMERCIAL JET TRANSPORTS

A *Prototype Survey Group* sent to Europe by the U.S. *Civil Aeronautics Administration* recently returned to the U.S.A. after studying the European commercial turbine aircraft already in service or available shortly (de Havilland "Comet," Vickers-Armstrongs "Viscount," Bristol 175, etc.). The committee's final report contained a clear warning that America still has nothing to equal today's British commercial jet aircraft. Britain's lead of three to five years could be overtaken and America's leading rôle in world aviation maintained only if decisive action is taken rapidly. The committee recommended that an immediate start be made on the design of a long-range jet transport capable of flying non-stop across the Atlantic from New York to London or Paris. This is likely to be the only way to meet British competition, since the "Comet" in its present version (four de Havilland "Ghost" engines) has not sufficient range for such non-stop flights. However, it should not be forgotten that a new version of the "Comet" is to have four Rolls-Royce "Avon" engines which will give it a much greater range than the original model.

Such is the voice of America. Britain's voice is possibly even more "dramatic." *Sir Miles Thomas*, Chairman of British Overseas Airways Corporation, announced a kind of *"all-out air transport war,"* when he stated early in August that BOAC was planning to put an impressive fleet of luxury jet liners into operation to "shrink the world in half." BOAC's world network would be operated by "Comets" five years from now.

The de Havilland "Comet" is of course a reality, but it does not yet exist in quantity. The fourth aircraft of the type made its first flight at the end of July. So far two aircraft have been ordered by the Ministry of Supply for research purposes, fourteen by BOAC, two for Canadian Pacific Air Lines and two for the French company Union Aéromaritime de Transport.

Meanwhile there are still a good many problems to be solved in connection with the commercial use of jet aircraft, and the Commonwealth Conference held in London from September 2nd to October 5th to investigate operational problems for jet airliners will have had plenty to occupy it. Its programme includes questions of air traffic control, ground organization, maintenance and so on.

THE U.S.A. GETTING TO WORK

However, where projects for jet or propeller turbine commercial transports are concerned, the U.S.A. is no longer empty-handed (Boeing, Douglas, Lockheed). At present experiments are being made with the Convair-Allison "Turbo-Liner" (two Allison T-38 propeller turbines) and a Chase XC-123A transport experimentally fitted with four General Electric J-47 jet engines (a machine derived from the slightly modified CG-20A military glider, the two jet engines being mounted in twin nacelles beneath the wings).

WHAT OF THE TRADITIONAL TYPES?

There are no more summer holidays for the design and development departments of the aircraft industry. Endless new designs have been coming out, both in the U.S.A. and in Europe—although the British industry has been keeping back its trump cards for the forthcoming S.B.A.C. Show.

Canada has announced the *DHC-3 "King Beaver,"* a development of the DHC-2 "Beaver" single-engined small high-wing monoplane commercial transport and military liaison aircraft, of de Havilland Aircraft of Canada. Slightly larger than its predecessor (span 58 ft. compared with 48 ft.), the "King Beaver" is designed for 14 passengers (gross weight 7,200 lbs., useful load 3,200 lbs.). A prototype, developed with financial support from the Royal Canadian Air Force, should be ready for testing in September, and quantity production is scheduled to start early in 1952.

Lockheed reports the first flight of the *"Super Constellation,"* orders for which have already been received to a value of roughly $250,000,000 (U.S.A.F., U.S. Navy, Eastern Air Lines, T.W.A., K.L.M., Air France, Pakistan International).

In Belgium the *S.A. Belge de Constructions Aéronautiques (SABCA)* is working on a project for a two-seater light jet fighter trainer, the *SABCA S.60*. In spite of the fact that the two engines used have a low thrust (about 880 lbs. each), the refined aerodynamic design is said to give the aircraft a maximum speed of 404 m.p.h. (or as much as 620 m.p.h. in a dive). So far this is only a project. Whether SABCA builds a prototype will depend on its getting a government subsidy for the design and production costs.

In France the first brief flights by the *Bréguet 960 "Vultur"* carrier-borne attack aircraft have been made. Fitted with an Armstrong-Siddeley "Mamba" propeller turbine (in the nose) and a Hispano "Nene" jet (in the tail) the Bréguet 960 is to have a maximum speed of 560 m.p.h. for a gross weight of 22,050 lbs. (cruising speed on propeller turbine alone: 215—250 m.p.h.). An interesting point is that endurance under cruising conditions is given as "several hours," a very welcome quality in an aircraft of this class. The same company is also developing a land-based single-seater version, the Bréguet 961, with more powerful A.S. "Mamba 3" or SNECMA TB. 1000 propeller turbine and SNECMA-ATAR or Hispano "Tay" jet.

CONGRESS PAYS OUT—BUT GRUDGINGLY

On August 6th the *House Appropriations Committee* of the U.S. Congress approved a *military budget of $56,062,405,890*, a record for peacetime. At the same time the Committee made several pungent criticisms of the U.S.A.F., attacking, for example, "chairborne" airmen who put in just sufficient time in the air to qualify for the extra pay granted "for the performance of hazardous duties"; warning against a "surplus of generals," constant transfers from one station to another, with "joy-rides" all over the States; ordering a reduction in civilian staff, particularly in press relations staff; and condemning the purchase of unsuitable civilian equipment, etc.

On August 14th, 1951, General Dwight D. Eisenhower, Commander-in-Chief of the Atlantic Forces in Europe, arrived at Rhein-Main airport, Frankfurt, to welcome the 433rd U.S.A.F. Transport Group newly arrived from the U.S.A. General Eisenhower was accompanied by (left to right): Colonel Harry W. Hopp, Officer Commanding the Group; Major General Dean C. Strother, Commanding General of the 12th Air Division; Colonel A. C. Strickland, Commandant of Rhein-Main air base.

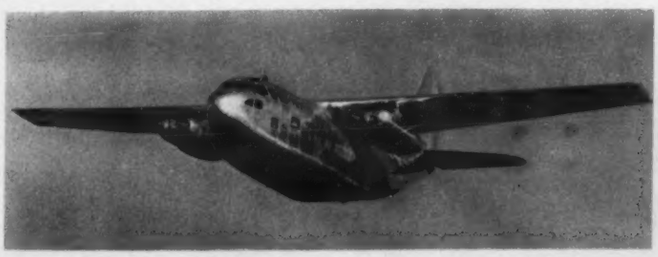
The total sum, having been cut by $1,542,608,500 from the original request, is divided among the three armed services as follows:—

U.S.A.F.:	$19,854,128,000 (after cut of $647,015,000)
Army:	$20,125,574,665 (after cut of $685,321,500)
Navy:	$15,552,143,225 (after cut of $194,272,000)

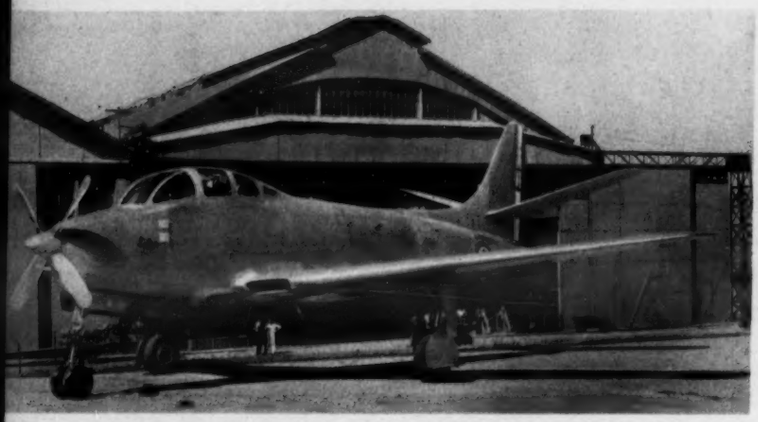
In sharp contrast to the "economy drive" of his colleagues of the House Appropriations Committee, *Carl Vinson*, one of the most influential Congressmen in the U.S.A., called for an increase in the *strength of the U.S.A.F. from 87 to 163 groups* instead of the 95 groups provided for in the budget. Vinson also demanded two more aircraft carriers of the class of the recently-approved 59,900-ton "Forrestal" (with deck said to be capable of carrying atom-bombers). He supported General Vandenberg, U.S.A.F. Chief of Staff, who in a recent Senate hearing said: "If the air war should be lost, the ground war will certainly be lost."

* Extracts from INTERAVIA AIR LETTER, daily international news digest, in English and French. All rights reserved.

The Chase XC-123A, first American jet-powered transport, derived from a Chase glider.



The first production model of the Lockheed L-1049 "Super Constellation" on its maiden flight.



The Bréguet 960 "Vultur" carrier-based attack aircraft, with Armstrong-Siddeley "Mamba" propeller turbine in the nose and Hispano "Nene" in the tail.

It's an old Canadian custom ! Every budding pilot who completes his first solo has his tie cut off and put into the "museum." Each tie carries the name of the pilot, the number of flying hours before the solo and date of solo.

EUROPE NOW GETTING DOWN TO IT

The U.S.A. have set to work seriously and are now refusing to be diverted from their rearmament drive by diplomatic skirmishings. Smaller European Atlantic powers are also gradually beginning to talk in facts and figures.

Figures from Belgium, prepared for the September Conference of the North Atlantic Treaty Organization, reveal that the Belgian armament programme for 1951/1952 (Fr. 14,200,000,000 ordinary and Fr. 15,900,000,000 extraordinary military credits) represents no less than 21.5% of the total military expenditure of all the European Atlantic powers. In addition, the Belgian representative on the Defence Production Board announced that during the period November 1st, 1950, to April 30th, 1951, orders for arms, ammunition and military vehicles to a total value of Fr. 5,500,000,000 were placed with Belgian industry. By the beginning of 1953 Belgium would have her own radar industry and would thus be able to overcome the weaknesses in the air raid warning system shown up by "Exercise Ombrelle." Finally, the Belgian Government declared itself willing to cooperate in financing the establishment of strategic reserves in the Belgian Congo.

The strength of the Belgian Air Force rose from 2,000 men in 1946 to 12,000 in the middle of 1951 and is to be increased to 20,000 by the beginning of 1953. In addition to the Republic F-84Es Belgium is to get a night fighter squadron of Gloster "Meteor" N.F.11s in 1952. The expansion programme also provides for three new Air Force bases, at *Velroux* near the present base of Bierset-Liège, at *Petit-Broghel* (Province of Limburg) and at *Sutendael* (near Asch).

Reports from Italy are becoming more substantial every month. The increasing importance of this country as a partner in the Atlantic Pact is illustrated by a number of events, viz: (1) the number of visits paid to Italy by Staff officers of the Atlantic Powers. During recent weeks there has been an inspection of Italian air bases by Air Marshal Sir Hugh Saunders, Deputy Commanding General of the Atlantic Pact Air Forces; a visit by Air Marshal Sir Robert S. Foster, Commander-in-Chief Home Command, R.A.F., to the Milan jet training centre; a visit of inspection to Italy by Field Marshal Montgomery, Deputy Commander-in-Chief of the Atlantic forces in Europe; a visit by General Aldo Urbani, Chief of Staff of the Italian Air Force, to command centres, bases and other installations of the U.S. Air Force in Germany. (2) Establishment of the headquarters of the Commanding General, Allied Air Forces, Southern Europe, in Florence. (3) Appointment of General Sergio Lalatta of the Italian Air Force as Deputy Commanding General, Allied Air Forces in Southern Europe.

W.E.W. Petter, designer of the English Electric "Canberra" jet bomber, recently left English Electric to join Folland Aircraft Ltd. He has now been made the firm's Managing Director.

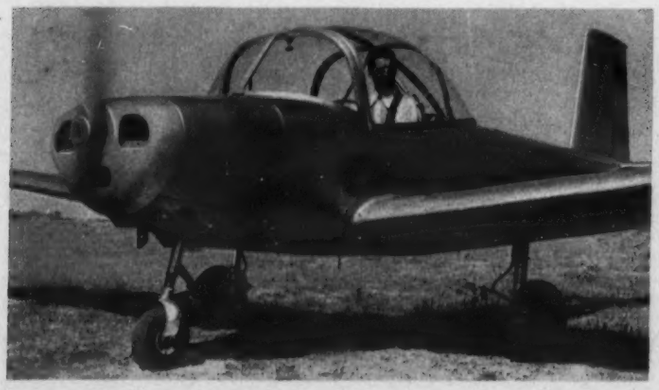
An even more important sign is probably the inclusion of the Italian industry in the Atlantic rearmament programme. The de Havilland "Ghost" jet engines built under licence by Fiat are now also to be supplied to France. A joint mission of the U.S.A.F., Wright Aeronautical Corp. and Curtiss-Wright recently went to Milan to place an order for the U.S.A.F. with the U.C.I.M.A. (Italian Machine Tool Constructors Association).

The Italian defence budget for 1951-1952 contains credits for the re-equipment of the aircraft industry in Southern Italy (Province of Naples). Provision is to be made for the quantity production of trainers under the Atlantic Pact procurement programme (Italian version of the Fokker S.11 and an Italian-designed trainer), and for the production of accessories and the execution of maintenance and overhaul work for Atlantic air units in the Southern Europe sector. Finally, these factories are to make parts for an unidentified jet aircraft for Italy and other Atlantic Pact countries.

"BABY AIR LIFT" FOR BERLIN

The restrictions placed by the Russian authorities in Eastern Germany on the movement of West Berlin goods have led to the inauguration of an air cargo service, so far privately operated, between West Berlin and Western Germany. The service is known unofficially as the "baby air lift" and is being run by PAA, Air France, BEA, Seaboard & Western, TAI (Transports Aériens Intercontinentaux). Over the weekend of August 4th and 5th a total of 31 flights was completed and over 230 tons of freight carried from West Berlin to Hamburg and Frankfurt. In London, Ernest Davies, Under-Secretary of State for Foreign Affairs, stated in the House of Commons that it might become necessary to ask for supplementary budget allocations if the "baby air lift" had to be subsidized. The cost of air carriage for the goods already awaiting transport is estimated as DM 100,000,000. "Baby" is growing...

The Iberavia I-11, Spanish two-seater sports and trainer aircraft.



Farnborough 1951

Aircraft of the Twelfth S.B.A.C. Air Display and Exhibition

This year's Society of British Aircraft Constructors' Show, held at Farnborough from September 11th to 16th—the twelfth since 1932—gave representatives of civil and military aviation, not to mention the aeronautical industry, from over 70 different countries an opportunity to see for themselves the latest products of the British aircraft industry. The aircraft shown included new, production model commercial transports, such as the " Ambassador ", " Viscount " and " Comet ", and high-speed day and night fighters, naval fighters, jet bombers and long-range reconnaissance aircraft, now ready for production for the R.A.F. Altogether 21 civil and 27 military aircraft types were shown, 37 of them in flight. As no aircraft with less then ten hours' test flying is admitted to Farnborough, even the so-called " static " display at the airfield was completely " realistic ". It was supplemented by an impressive collection of the newest British power plants—turbine or piston type, rockets and even a new type of composite engine—and by the usual multitude of first-class products of the accessories industry.

*

Armstrong-Whitworth, a member of the Hawker-Siddeley Group, showed the two-seater " *Meteor N.F. 11* " night fighter (two Rolls-Royce " Derwent 8 ") with extended radar nose, pressure cabin and wing-tip drop tanks, which is in quantity production for R.A.F. Fighter Command. Four 20-mm cannon in the wings ; span, 43 ft. 0 in. (13.1 m) ; length, 48 ft. 6 in. (14.8 m).

Auster's contributions were the three-seater " *Aiglet Trainer* " (D.H. " Gipsy Major 1 ") and " *Model S* " (Cirrus " Bombardier ") two-seater military liaison aircraft, and a new *ambulance and freight aircraft* (Cirrus " Bombardier "), all of them braced high-wing monoplanes.

Blackburn & General Aircraft presented their sturdy four-engined all-metal " *Universal Freighter* " high-wing monoplane (Bristol " Hercules 261 " of 2,000 h.p.), an efficient civil and military transport, capable of carrying a 15-ton load, including unwieldy cargos such as a bus or light tanks. Reversible pitch propellers reduce the landing run to less than 200 yds. (180 m) and, together with the double twin undercarriage (non-retractable) and twin nose wheel, enable the aircraft to operate from even auxiliary landing grounds. Span, 162 ft. (49.5 m) ; length, 98 ft. (30 m) ; max. speed 225 m.p.h. (363 km/h) ; military designation GAL-60.

Boulton Paul was represented by its *P. 111 delta-wing research aircraft* (Rolls-Royce " Nene "), which surprised many of the onlookers with the ease with which it executed short take-offs, fast flights, steep turns, rolls, etc., in spite of its unusual shape. Along with the two Avro delta-wing aircraft, the P. 111 proved that the new shape is to be taken seriously. Landings were made with and without brake parachutes, but in the latter case with considerably greater angle of incidence. Span, 33 ft. 6 in. (10.2 m) ; length, 26 ft. (7.9 m) ; elevons (i.e. combined elevators and ailerons).

The *Bristol 171 helicopter* (Alvis " Leonides ") and a " *Proteus-Lincoln* " bomber arranged as a " flying test bed," were both demonstrated in flight. The latter has been used since August, 1950, for the airworthiness tests of two Bristol " Proteus " propeller-turbine engines. Taking off with the aid of two R.-R. " Merlin " reciprocating engines, the " Lincoln " was demonstrated in flight with the " Merlins " shut off and the " Proteus " running.—One of the main points of attraction was naturally the " conducted tour " over the " *Brabazon 1* " long-range experimental aircraft (eight 2,600-h.p. Bristol " Centaurus " engines coupled in pairs driving contra-rotating propellers), particularly interesting points being the extensive measuring equipment (including five ciné cameras, each for half a hundred instruments) and the water ballast tanks.—Span, 230 ft. (70 m) ; length, 177 ft. (54 m) ; gross weight, 285,000 lbs. (129 tonnes) ; max. speed, 300 m.p.h. (483 km/h). Finally there was the twin-engined *Bristol 170* " *Freighter* " (Bristol " Hercules 730,") which carried a complete Bristol 171 helicopter in its capacious fuselage.

The *de Havilland Enterprise* was represented by a total of *nine* aircraft, *de Havilland Aircraft Co.* showing the first *40-seater* " *Comet* " for BOAC's South Africa service (four D.H. " Ghosts ") with bogey-type undercarriage, boundary layer fences, suppressed aerials and luxurious cabin equipment in the " Static Show," and its four-engined 14/17-seater " *Heron* " (D.H. " Gipsy Queen 30 " ; fixed undercarriage) and twin-engined 8/11-seater " *Dove* " (D.H. " Gipsy Queen 70 " ; retractable undercarriage) in flight. Cruising speed of the " Comet " 490 m.p.h. (790 km/h) ; max. range, 3,540 miles (5,700 km) ; crew cabin for four with oxygen apparatus, Machmeter, Zero Reader and periscope sextant. For the first time a price has been quoted, namely £450,000.—A two-seater " *Vampire-Trainer* " (D.H. " Goblin 3 ") for the R.A.F. was demonstrated by Mr. J. W. Wilson and a two-seater " *Sea Venom* " carrier-based all-weather fighter (D.H. " Ghost ") for the Royal Navy by Squadron Leader J. Derry, both of whom gave masterly demonstrations of acrobatic flying. The *de Havilland Engine Co.* showed a " *Reheat Venom* " experimental version (with D.H. " Ghost " and afterburner) with a noticeably improved take-off and climbing performance, and *de Havilland Propellers, Ltd.* demonstrated for the first time the braking effect of reversible

pitch propellers in a turbine commercial aircraft, the 18/22 seater Handley Page "*Marathon 2*" (two Armstrong-Siddeley "Mambas,") the landing run being less than 170 yards (155 metres). *Airspeed Division* of de Havilland showed one of their first "Ambassador" medium-range commercial transports in its operational version (two 2,600 h.p. Bristol "Centaurus 661s") for 47 passengers. Twenty of these aircraft have been ordered by B.E.A., where they will be known as the "Elizabethan Class" airliners. (One "Ambassador" is already flying on the London-Paris route, and five others are to go into operation at the end of September.) An unexpected feature was the arrangement of the seats: the first four rows, each comprising four or five seats, face backwards, the rear six rows on the other hand face forwards. Gross weight 52,000 lbs. (23,590 kg); cruising speed, 300 m.p.h. (483 km/h); max. range, 1,560 miles (2,500 km); pressure cabin. — Finally, *de Havilland Company of Canada* presented their popular two-seater "*Chipmunk*" trainer (D.H. "Gipsy Major.")

English Electric's "Canberra P.R. 3" long-range reconnaissance version (two Rolls-Royce "Avon") of the well-known bomber (R.A.F., U.S.A.F. and R.A.A.F.) was shown in flight. Designed for very great operating heights, the "Canberra P.R. 3" will probably have drop fuel tanks so as to increase its range still further. Visitors were reminded that a bomber of this type recently covered the 2,072.79 miles (3,335 km) across the Atlantic from Aldergrove (Northern Ireland) to Gander (Newfoundland) in 4 hrs. 18½ mins. Span, 64 ft. (19.5 m); length, 66 ft. 8 ins. (20.4 m); in addition, the "*Sapphire Canberra*" (two Armstrong-Siddeley "Sapphires,") which is to be produced under licence in the U.S.A., was shown taking off, in flight, and landing. Span, 64 ft. (19.5 m); length 65 ft. 6 in. (20 m).

Fairey Aviation, a specialist in carrier-borne anti-submarine aircraft, was represented by the extremely powerful looking "*Gannet*" (Armstrong-Siddeley "Double Mamba") and the slighter—though no less powerful—"*Firefly Mark 7*" (Rolls-Royce "Griffon"). Both types are three-seater low-wing monoplanes with folding wings and contra-rotating propellers. Span, 54 ft. 4 ins. (16.6 m) and 44 ft. 6 ins. (13.6 m), respectively. Both are in quantity production for the Royal Navy. The "Gannet," which was also demonstrated in flight with "half" a power plant, i.e., which took off with one stationary propeller (an unusual sight), was fitted with a retractable radome in the tail of the fuselage and with a long bomb bay; the "Firefly Mark 7" carried sono-buoys in two airfoil-shaped boxes suspended under the wings.

Gloster's ground-attack "Meteor," a single-seater prototype developed especially for low-level attacks (two Rolls-Royce "Derwents," wing-tip drop tanks, 24 95-lb. rockets, four 20-mm cannon) attracted particular attention in the hands of Test Pilot Squadron Leader Janusz Zurakowski (a former Polish Air Force pilot) who gave an aerobatic demonstration of extraordinary brilliance. On the afternoon of September 11th he took his aircraft with full military equipment repeatedly up in long, vertical climbs, hung suspended an instant, then came down in spins. On September 12th Zurakowski executed—after similar preludes—a cartwheel consisting of a compromise between a tail slip and a stalled turn. Span of the ground-attack "Meteor," 37 ft. 2 ins. (9.9 m); length, 44 ft. 7 ins. (13.6 m).

Handley Page put up one of the two 40/70-seater "*Hermes 5*" prototypes (four 2540-h.p. Bristol "Theseus" propeller-turbines) which had an anti-skid brake-pressure regulator to reduce the landing run to the absolute minimum. Span, 113 ft. (34.5 m); length, 95 ft. 6 ins. (39.2 m); max. cruising speed, 355 m.p.h. (540 km/h). The production version of this aircraft, however, is to have 3,400-s.h.p. Bristol "Proteus" propeller-turbines. The Company also showed a 22-seat "*Marathon 1*" feederline transport (four D.H. "Gipsy Queen 70s") in the Static Show, as well as the "Marathon 2" already mentioned (cf. de Havilland).

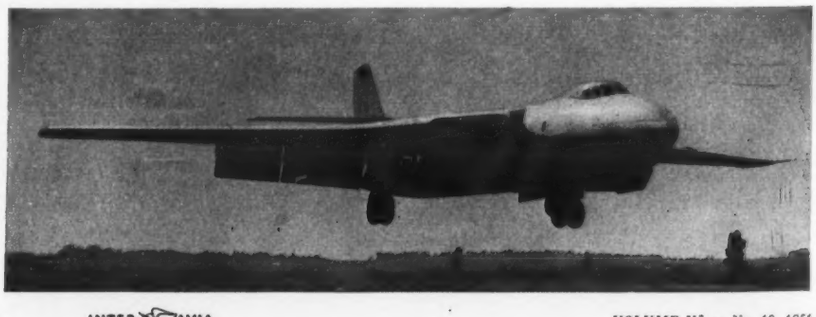
Hawker flew the *P. 1052* carrier-based fighter prototype (Rolls-Royce "Nene")—the smallest aircraft in the Show, with a span of 31 ft. 6 ins. (9.5 m) and a length of 39 ft. 7 ins. (12.1 m)—and its new R.A.F. fighter, the *P. 1067* (Rolls-Royce "Avon") which was officially reported to be faster than the American F-86 or Russian MiG-15. These two swept-wing types were shown one after the other by the same pilot (the announcer called him a "quick-change artist,") Squadron Leader N. Duke, whose endurance in very close turns (apparently up to 6 g) and in wide loops and very fast rolls aroused admiration. During his slightly inclined flights at very low altitude Squadron Leader Duke probably reached speeds approaching that of sound; in any case spectators on the ground were struck by a shock wave almost like an explosion, never before experienced at such intensity. Another new machine was Hawker's latest product, the *P. 1072 single-seat fighter* (Rolls-Royce "Avon" and Armstrong Siddeley "Snarler" rocket engine) with bifurcated turbine air intake and dual jet nozzle. The new fighter was one of the surprises of the Show.

Napier demonstrated its new, extremely economical, 3,000-h.p. "*Nomad*" composite engine (fuel consumption under cruising conditions, 0.360 lbs/e.h.p.=163 g/e.h.p.) installed in the nose of a *Lincoln* four-engined bomber. In the "Nomad" a twelve-cylinder Diesel engine drives one-half of a contra-rotating propeller and passes its exhaust gases into a turbine which drives the other half of the propeller. The turbine also drives an axial and a radial compressor which are connected in series and supply fresh air to the Diesel engine. — Take-off power, 3,000 s.h.p. plus 320 lbs. (145 kg) residual thrust; dry weight, 4,200 lbs. (1900 kg); over-all dimensions, 126½×58¼×49¼ ins. (3.2×1.5×1.25 m).

Percival showed its new two-seater "Provost" R.A.F. trainer (Alvis "Leonides," 550 h.p.) an aircraft with impressive aerobatic performance (pilot R. G. Wheldon), and the 8 to 12-seat "*Sea Prince*" *navigation trainer* (two Alvis "Leonides") for the Royal Navy. An air photography and survey version of the twin-engined type was also shown (*"Survey Prince,"*) which has been ordered by Switzerland, Thailand (Siam) and Tanganyika.

A. V. Roe & Co. had the "*Ashton*" research aircraft (four R.-R. "Nene,") the well-known "*Shackleton*" reconnaissance and anti-submarine aircraft (four R.-R. "Griffons") and the *Avro 707B* delta-wing aircraft (R.-R. "Derwent") in flight. The 707B, which unlike the Boulton Paul P. 111 has separate elevators and ailerons, surprised onlookers by its extraordinary manœuvrability, and also landed with and without braking parachute. Span 33 ft. (10.1 m); length, 41 ft. 10 in. (12.8 m). Another delta-wing aircraft, the Avro 707A, the third of the series, was to be seen in the Static Show. Span 34 ft. 2 ins. (10.4 m); length, 42 ft. 9 ins. (13.1 m). Apart from the slight differences in dimensions, the main difference between the two delta-wing air-

New engines and aircraft at Farnborough: left, the Napier "Nomad" composite engine in the nose of a World War II Lincoln bomber; right, the new Vickers "Valiant" four-jet bomber about to land.



craft is the arrangement of the air intake: in the 707B it is on top of the fuselage and in the 707A in the edge of the wing root.

Scottish Aviation showed the 4/5-seater "*Prestwick Pioneer Mark 2*" slotted-wing high-wing monoplane (Alvis "Leonides") in extremely short take-offs and landings. The "Pioneer" used only half the width of the runway.

Shorts' new aircraft was the four-engined *SA/4 jet bomber* (R.-R. "Avons" in vertical double nacelles), a machine much more impressive in flight than on the ground. — Span, 109 ft. (33.3 m); length, 102 ft. (31 m). — The 5/8-seater "*Sealand*" amphibian (two D.H. "Gipsy Queen 70s) was also shown in flight, part of the time with one engine stationary. It is already in operation in Norway, Yugoslavia and Borneo.

Vickers-Armstrongs contributed six aircraft types, including two new designs. In addition to the very impressive and graceful four-engined "*Valiant*" *jet-bomber* (first flight May 18th, 1951) the new twin-engined, carrier-based, single-seat fighter, *Supermarine* 508 (first flight August 31st, 1951) was also on view. Both types are fitted with the R.R. "Avon," the standard power plant for all the newer British fighters and bombers. Whereas, however, the "Valiant" has a markedly swept wing, the wing of the 508 is straight. The fighter also has a butterfly tail unit which not only provides free passage for the exhaust gases from the engines on either side of the fuselage but also considerably reduces interference drag of the tail. The "Valiant" is designed for the long-range transport of atomic bombs and is referred to as the "most powerful offensive weapon ever produced"; the Supermarine 508 is considered to be the fastest carrier-borne fighter. In place of the "Avon"-powered "Swift," which made a belly-landing on the eve of the show, the *Supermarine 535 swept-wing fighter* (R.R. "Nene") was demonstrated. The "Swift" is the second swept-wing on order for the R.A.F. (together with the P. 1067). The *Supermarine Type 538*, a new version of the "Attacker" single-seater carrier fighter (R.R. "Nene"; tail-wheel; auxiliary tank under the fuselage, four 20-mm cannon, 95-lb. rockets, etc.) and the "*Varsity*" twin-engined trainer (Bristol "Hercules") were also shown. Among the turbine-powered commercial transports BEA's elegant four-engined "*Viscount 700*" (R.R. "Dart") for 48 passengers won universal acclaim. It was demonstrated with two engines stationary.

Westland Aircraft showed its "*Wyvern 4*" carrier-based fighter and naval strike aircraft (A.S. "Python" propeller-turbine and contra-rotating propellers) with full military equipment (torpedo, 95-lb. rockets, four 20-mm cannon) and its well-known *S-51* four-seater helicopter (Alvis "Leonides.") A series of other helicopter projects were to be seen in the form of models.

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An illustrated report on the S.B.A.C. Air Display and Exhibition will be published in our November issue.

The "Wasserfall" Remote-Controlled A/A Missile

by RUDOLF H. REICHEL, Frankfurt a.M.

Among the anti-aircraft weapons with rocket drive conceived in Germany during the war the "Wasserfall" projectile developed at Peenemünde occupies a particularly outstanding place. Although it was never used operationally, work on its development provided knowledge in a completely new sphere, which might well be of value in rocket research even today. Compared with the V2 artillery missile,[1] the following additional problems had to be dealt with:—

a) supersonic aerodynamics of a missile with three-dimensional guidance and suitable measuring methods in the wind tunnel;
b) introduction of remote-control systems and preliminary work on an automatic target-seeking device;
c) realisation of a method of automatically firing the charge at the shortest distance from the target (proximity fuse);
d) new propellant combinations and a suitable valveless power plant.

*

[1] Cf. S. F. Erdmann: "The Development of the V2" in INTERAVIA, Review of World Aviation, Vol. 2, May and June 1947.

Early in the war *Dr. V. Braun*, head of the Peenemünde research centre, suggested the development of a guided supersonic missile for anti-aircraft defence. But it was not until 1942 that the Germans were forced to a recognition of the importance of a weapon of this kind. At that time there were merely a few subsonic projects for A/A missiles under development, and their operational utility was being constantly reduced by the ever-increasing height and speed of enemy raiders. Such projects could only provide an interim solution and at best served to bridge a temporary gap. Only a supersonic A/A missile was equal to the new conditions.

The object of the "Wasserfall" was two-fold; on the one hand to break up enemy bomber formations so that the fighters could come to grips with them, and on the other to attempt to destroy fast, high-flying single aircraft. The main points insisted on by the military authorities were as follows:—

a) successful use against air targets whatever their evasive tactics (turns, dives, etc.) provided these were based on a load factor of not more than 2;
b) maximum height of enemy 15,000 m. (49,000 ft.); maximum speed 720 km/h (450 m.p.h.);
c) maximum controllable range of the missile approx. 25 km (15½ miles)
d) weight of explosive charge to be carried 250 kg (550 lbs.)

Further requirements were that it should be capable of several months' storage with full tanks, be ready for immediate use at all times regardless of ambient temperature, be as simple as possible to operate and require the minimum equipment on the ground.

Work was begun at Peenemünde during the autumn of 1942 and carried out in parallel with the development of the V2. The aid of the aircraft industry and of various institutes was secured. Research facilities available at Peenemünde included a propellant laboratory, a missile test bench, three oven test benches, a floating oven and missile test bench, a test bench for experimenting with new injection systems and for testing the behaviour of propellants, and the workshops of the V2 project.

Initial plans.

What size and shape would the missile have to be to fill all the requirements perfectly? This was the very first question. If it were made too large it would overload

production capacity, in view of the large number required. A rocket-propelled missile 88 cm (34 $^{2}/_{3}$ in.) in diameter and about nine times as long was decided upon. All other data had to be selected arbitrarily, as there was no previous experience to go on. This was particularly true where the aerodynamic form and the power plant were concerned. It was subsequently found that many of the original assumptions could not be maintained, a fact which caused considerable difficulties. The development of the "Wasserfall" is an excellent example of the value of basic research.

The original values decided upon were as follows :— rocket thrust 8 tonnes, propellant consumption 42 kg/sec, duration of propulsion 45 secs, pressure in combustion chamber 16 kg/cm², pressure at outlet of Laval duct 1 kg/cm², effective exhaust velocity 1870 m/sec, take-off weight 3500 kg, weight in free flight (empty) 1500 kg, speed at end of combustion approx. 960 m/sec. (Mach number approx. 2.9), total time of flight 90 secs.

Aerodynamics

The aerodynamic development was begun early in 1943 in the Peenemünde supersonic wind tunnel and later continued at Kochel (when the wind tunnel was moved there). The air raid on Peenemünde in August 1943 did not damage the wind tunnel, which was of significance insofar as the most important measurements had not yet been made.

As the A/A missile had to keep to certain pursuit curves it had to be part shell, part aircraft. No aerodynamic data being available for supersonic aircraft at this time, the lay-out had to be based on experiments and measurements already obtained with the V2. Up to that time the V2 was the only missile which could satisfactorily pass through the sonic range and reach higher Mach numbers. Chiefly because of the urgency of the project the basic form of the V2 and the shape of the latter's tail surfaces were largely retained. However, the movable tail surfaces and the jet vanes had to be redesigned. For lay-out of the former there were only a few wind tunnel measurements made with the A9 model (further development of the V2 with wings) available. Furthermore it was agreed that some form of wing was essential. Circular lifting surfaces were out of the question because of their excessive drag. A symmetrical wing cross (with planes set at right angles to one another) was therefore selected.

Fig. 1 : Dynamic pressure (q) and Mach number (Ma) of the "Wasserfall" A/A missile plotted against time of flight. Unbroken lines relate to flat trajectories, broken lines to steep trajectories.

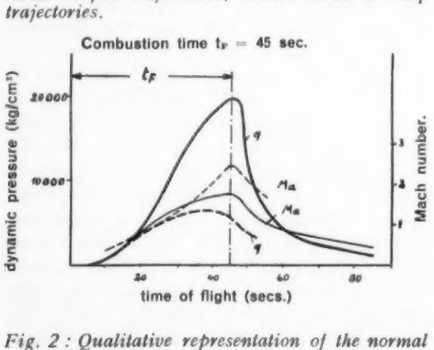
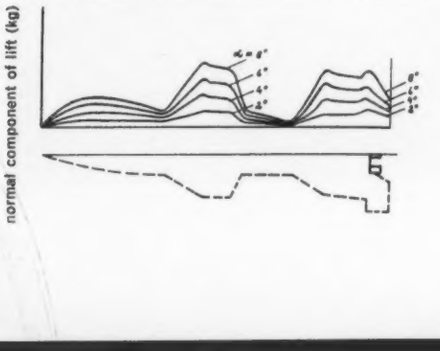


Fig. 2 : Qualitative representation of the normal components of lift in supersonic flight at various angles of incidence. Below, outline of A/A rocket.



The aerodynamic design was based on the fact that the missile had to be capable of withstanding a load factor of up to 12 (for a free flight weight of 1500 kg). To make sure of the greatest likelihood of the missile's reaching its target the load factor had to be much greater than that of the aircraft. Maximum lift was therefore $12 \times 1500 = 18000$ kg. Since the trajectories had been calculated on the basis of estimated aerodynamic factors, the dynamic pressures to be expected were thus roughly known. They naturally depended on the momentary altitude of the missile and on the nature of the trajectory (steep, flat, medium) (cf. fig. 1). The variation in the lift and drag coefficients of the body and tail versus angle of incidence and Mach number was known from the V2 measurements. Without the cross wings the angle of incidence would have been very large, the drag intolerably high and the lift distribution unfavourable. As the maximum angle of incidence was 15° for subsonic and 8° for supersonic flight, the cross wings had to be so designed as to provide the remaining lift with as little drag as possible.

In order to make the power units for the steering mechanism as light as possible the displacement of the centre of pressure at all speeds had to be reduced to a minimum. This was done by means of numerous wind tunnel experiments. The aerodynamic moments to be compensated by the movable control surfaces are built up by the normal components of the lift along the missile (fig. 2) and the respective lever arm (about the centre of gravity). But it is a well-known fact that during the transition from the subsonic to the supersonic range, a marked displacement of the distribution of lift occurs. In addition to this the efficiency of the movable control surfaces falls off considerably with increasing Mach number (cf. fig. 3). Understandably, the smallest change would occur if centre of pressure and centre of gravity were always at the same point. However, there is no way of preventing the displacement of the centre of pressure, owing to the changes in the angle of incidence, or the displacement of the centre of gravity due to the progressive emptying of the fuel and oxydizer tanks during powered flight (fig. 4). Moreover a certain part is also played by the variation in the moment of inertia (as the tanks empty), which influences the angular acceleration of the missile attainable during its pursuit flight.

During the wind tunnel tests all kinds of wing forms (e.g. those shown in fig. 5) were experimented with and the position of the wings was varied within certain limits. Furthermore, the qualities of various control

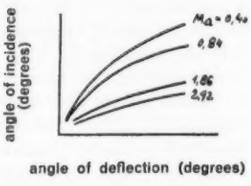
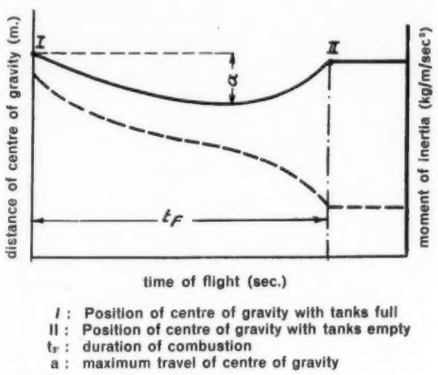


Fig. 3 : Qualitative representation of possible angles of incidence—plotted against control surface deflection and Mach number—for a given design of tail surfaces.



I : Position of centre of gravity with tanks full
II : Position of centre of gravity with tanks empty
t_F : duration of combustion
a : maximum travel of centre of gravity

Fig. 4 : Distance of centre of gravity from the tail edge (unbroken line) and qualitative representation of the inertia moment (broken line) plotted against time of flight.

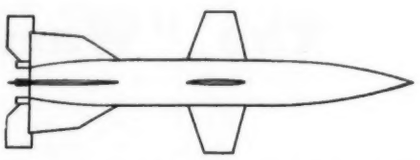


Fig. 5 : One of the many wing designs tried out in the wind tunnel for the "Wasserfall" A/A missile.

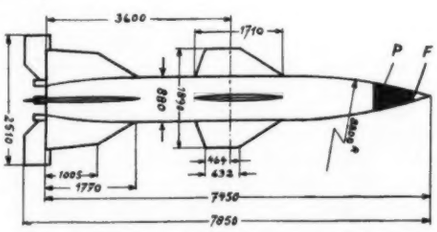


Fig. 6 : Final form of "Wasserfall" with warhead (P) and fuse (S). The wind tunnel model was approx. 300 mm long.

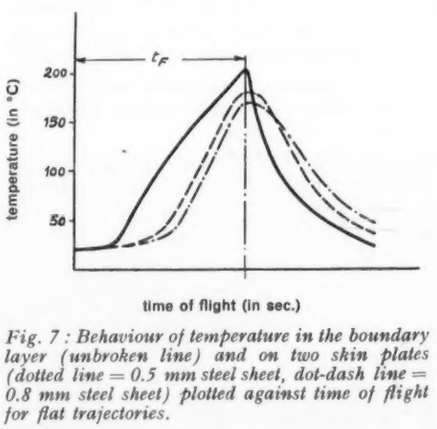


Fig. 7 : Behaviour of temperature in the boundary layer (unbroken line) and on two skin plates (dotted line = 0.5 mm steel sheet, dot-dash line = 0.8 mm steel sheet) plotted against time of flight for flat trajectories.

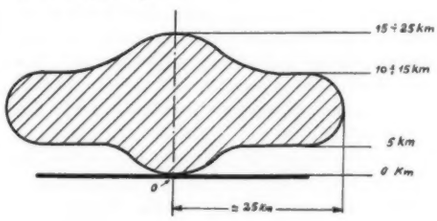
surfaces had to be examined and the hinge moments for the subsonic and supersonic ranges had to be defined. This was done in relationship to the displacement of the centre of gravity and centre of pressure. In addition Schlieren photographs were made and the break away of the boundary layer observed. Eventually control surface forms were found which met the requirement of continuous controllability in subsonic and supersonic flight with very small hinge moments. Slightly more favourable conditions arose in that later calculations of the flat trajectory indicated that a Mach number of no more than 2 was to be expected, with the required angles of incidence and load limits being maintained.

The ultimate result of all this painstaking detail work was the final form of the missile, as is shown in fig. 6. The length of the body was 7450 mm. or 8.46 calibre, the radius of curvature of the nose 10 calibre. The movement of the centre of pressure was satisfactory. Further experiments were undertaken to measure the jet influence and the surface temperatures in relation to the time of flight (fig. 7).

Controls.

Fig. 8 shows the limits within which the " Wasserfall " could be controlled up to the required maximum horizontal firing range

Fig. 8 : Effective range of " Wasserfall " when launched from point 0.



of 25 km., as far as it could be estimated from the range of the missile and its controllability at a given spot (maintaining a maximum centrifugal acceleration of 12 g). The steering mechanism was of such dimensions that at high dynamic pressures only a small control surface deflection could be obtained. For the required angles of incidence (15° in the subsonic and 8° in the supersonic range) the angle of deflection of the control surfaces varied, according to the flying attitude, between 4° and 15°.

It was intended that control should be on the beam principle (fig. 9). Immediately after launching the missile would automatically follow the beam of radar unit II, and after deflection into the direction of the target it would be taken over by unit I which would continuously follow the target.[2] In the last flight phase the missile—now independent of the beam—would be guided to the target by means of its own target-seeking device. At that time development was not sufficiently advanced to enable this plan to be realised. The two radar units alone were used, but the automatic device in the missile had to be replaced by a system of

[2] Cf. L. Brandt : " German Radiolocation in Retrospect I ", Vol. 5, No. 6, p. 321.

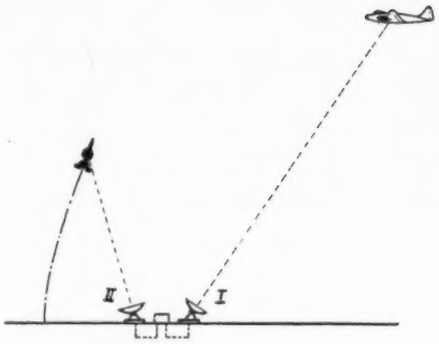


Fig. 9 : Diagram of remote-control arrangement for the " Wasserfall " with the aid of two Fu. M.G.75 radar units. Radar set I remains sighted on the target, while set II follows the missile in its first stage of flight. Later on radar set I takes over. The influence of the " lead " is seen from the rocket's direction of flight.

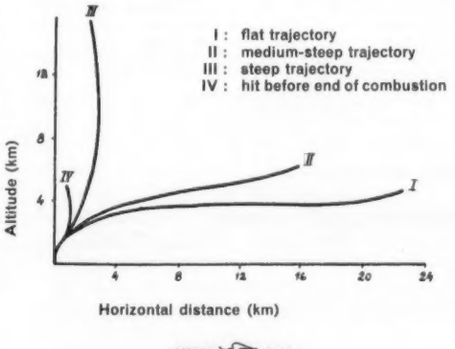
radio control from the ground. Measurements of the deviation from the beam provided the bases for corrective impulses, which were transmitted to the missile's steering mechanism by means of a stick arrangement on the ground. The control impulses were automatically limited, to avoid exaggerated changes in the missile's attitude.

Launching was always vertical. After six seconds deflection of the missile began. During the deflection the maximum angles of incidence had to be taken into consideration. After about 20 seconds deflection was complete, after which remote control by means of the three-point system (launching point – missile – target on a straight line) came into operation. Here a " lead " was necessary, according to the attitude of the missile, and the height and distance of the target. Even when the missile was remote-controlled by hand (by means of a stick apparatus) the necessary " lead " had to be given automatically, as it was too difficult for the missile director to estimate.

The A/A missile had four power units, each actuating one movable control surface and one jet vane. The jet vanes provided adequate steering immediately after take-off, while dynamic pressures were insufficient, and augmented the effect of the movable control surfaces in the subsonic range. — The power units of the steering mechanism worked on either the hydraulic or the electrical principle. Their greatest hinge moment was approx. 50 mkg.

Trajectory calculations for approximately 100 different cases (cf. fig. 10) and measurements in the supersonic wind tunnel provided

Fig. 10 : Some of the " Wasserfall's " characteristic trajectories :—



the basis for the entire control system. The calculations were checked by means of model tests. The complicated differential equations of the equilibrium of forces and moments were imitated by means of electrical circuits. Finally it was possible to carry out the first controlled ascents of the " Wasserfall " (about 30).

Propellants.

The only propulsion system which could provide the required free impulse of 360,000 kg/sec. was a liquid propellant rocket engine. Other important requirements were simplicity and constant operational readiness. The ethanol/liquid oxygen combination, such as was used in the V2, was therefore out of the question.

Experience had shown that propellant combinations on the basis of nitric acid as oxidizer came nearest to filling the required conditions.[3] Incidentally it was also planned to use a combination containing nitric acid for a development of the V2.

As the intention was to use the " Wasserfall " on a large scale the question of raw materials was of the utmost importance. Combustibles had been found which ignited spontaneously on contact with nitric acid, some of them by-products of Buna. But the usefulness of these combustibles was greatly limited by operational conditions. For example they had to remain without solid deposits down to a temperature of —40° C and viscosity was not to exceed specified values. Consequently combustibles were selected which fulfilled these conditions and had mixed with them *additional substances* (amines, pyrocatechin, hydroquinones, etc.) which ignited spontaneously on contact with the oxidizer.

The first combustible used, " *Visol 6*," consisted primarily of a *vinyl ethyl ether*. Its ignition delay—i.e. the time elapsing between contact of the two propellant components and the actual ignition—was satisfactory. It was of the order of 2/100 to 6/100 second (for the " Wasserfall " oven). The vertical position of the combustion chamber had a favourable effect here, as it largely prevented the collection of excessive quantities of propellants inside the oven.

By-products from coal-tar containing *pyrocatechin* also contained spontaneously-igniting substances. Thus, when it became difficult to obtain visols, combustibles with a base of pyrocatechin were used instead. Once the initial difficulties of ignition behaviour and aging had been overcome good results were obtained. Consequently it was decided in 1944 to switch all missiles on the so-called " Vesuvius " programme, i.e. those using nitric acid or nitrogen tetraoxide, to these combustibles. These so-called optoline combustibles consisted of about 10 % pyrocatechin, together with aniline, visol and aromatics. To a greater and greater extent normal petrol was also added and it was intended to replace the " standard combustibles " by petrol fuels.[4]

[3] In particular the Bayerische Motorenwerke (BMW) had from the start based their rocket development on propellants containing nitric acid. (Eds.)

[4] At the end of the war BMW had combustibles which were composed of 90 % petrol and 10 % additional products and were self-igniting. (Eds.)

The spontaneously igniting property of propellants is of course required only for starting. Once combustion has begun it can continue even with poor igniters such as petrol or gas oil. Towards the end of the war therefore gas oil and brown coal tar oil were used in 8-tonne combustion chambers with outstanding success.

In the early stages of the development of " Wasserfall " pure (98%) nitric acid was used as oxidizer. Later less nitric acid diluted with a 10% admixture of sulphuric acid was used. This was known as M 10 acid mixture.

Some of the difficulties that had to be overcome in the search for the ideal fuel can be seen from the following example :— To save time, the planning section had already fixed the dimensions of the projectile and its tanks before the results of wind tunnel tests and experiments on propellants and power plant were available. It was therefore to be expected that any major alterations would completely upset the complicated structure of development work. This indeed was the case when propellant experiments showed that a different arrangement of the tanks would be necessary. At this stage, however, it was impossible to alter the design, as initial steps for large-scale production had already been taken. Moreover detailed measurements had been made in the wind tunnel on the basis of the originally estimated behaviour of the centre of gravity. The controls group had also taken the planning section's original values and the wind tunnel measurements as basis. Thus the only possible way of solving the problem was to change the density of the combustible so that the original estimates for the movement of the centre of gravity could be adhered to, without reducing the quality of the fuel. This is in fact the line that was followed.

DETAILS OF THE " WASSERFALL "

(in the final stage of development reached)

Length of projectile (without control surfaces)	7.45	m.
Length of projectile (with control surfaces)	7.85	m.
Diameter of body	0.88	m.
Maximum width	2.51	m.
Rocket thrust	8	tonnes
Combustion chamber pressure	20	kg/cm²
Pressure at end of Laval duct	1	kg/cm²
Duration of combustion	42	sec.
Free impulse	336,000	kg/sec.
Take-off weight	3,500	kg.
Warhead	250	kg.
Weight of propellants	1,935	kg.
Made up of : acid (90% HNO_3 + 10% H_2SO_4)	1,500	kg.
combustible (optoline)	345	kg.
nitrogen (in high pressure ball)	90	kg.
Weight in free flight	1,565	kg.
Mass ratio : take-off/free flight	2.24	
Propellant consumption	44	kg/sec.
viz : acid	35.8	kg
combustible	8.2	kg/sec.
Specific propellant consumption	5.5	kg/sec.
Mixture ratio : combustible/acid	0.23	
Effective exhaust velocity	1,780	m/sec.
Effective acceleration after launching	1.29	g.
Effective acceleration at end of combustion (according to trajectory angle)	4.11 g. to 5 g.	
Angle of incidence in subsonic flight	15°	
Angle of incidence in supersonic flight	8°	
Maximum load factor on controls	12	g.
Speed of flight at end of combustion	appr. 660	m/sec.
Maximum altitude of ascent	24,000	m.

Technical description

Unlike the V2, the " Wasserfall " did not have a stressed body structure, but the two propellant tanks took over this function. They were designed to take a maximum load factor of 12 g. As it was an expendable projectile as little strategic material as possible was used. Normal carbon steel with a tensile strength of 50 kg/mm² was largely used. The cross wings and the tail surfaces were also covered with steel sheet 0.5 to 0.8 mm, thick. All fixed joints were welded. The construction of the projectile is shown in fig. 11.

The *power plant* was of particularly simple design :— (1) feeding of propellants under pressure without pumps : (2) valveless power plant ; (3) spontaneous ignition of propellants.

The missile rose vertically under its own power from a mobile platform (fig. 12). For starting the rocket engine, the black powder charge of a so-called " firing membrane " *d* (cf. fig. 11) was electrically ignited, which —after the operation of threeway safety cock *e*—opened the way for the nitrogen to leave its high pressure chamber *c* and enter a pressure reducer *f*. The latter had to function perfectly, since an irregular feeding pressure might have endangered the combustion process. The two bursting membranes *g*, above the propellant tanks were then " aired " via a branched lead, and then opened the way to the tanks at a pressure of about 8 atm. Here pressure was built up until the lower bursting membranes g_2 also gave way. The combustible then passed directly into the injection nozzle ; on the other hand the acid had to make a detour through the cooling jacket. This was desirable, since if the combustible ran in first, in a self-igniting system, safe starting was assured. In addition the sections of the radial acid channels in the injection nozzle (cf. fig. 15) were reduced by means of a pastelike substance so that the brief chemical process of dissolving the paste would enable the combustion chamber pressure to build up gradually. Between bursting membranes g_2 and the combustion chamber elastic connecting hoses *n* were built into the combustible and acid leads.

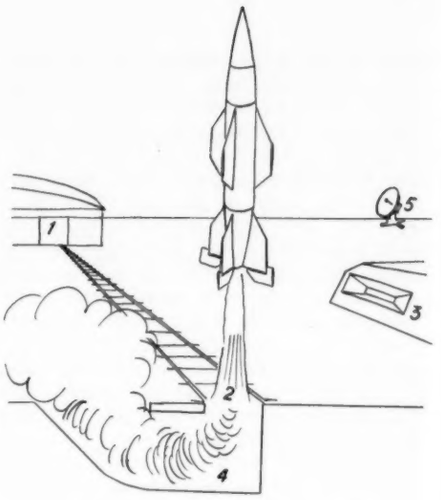


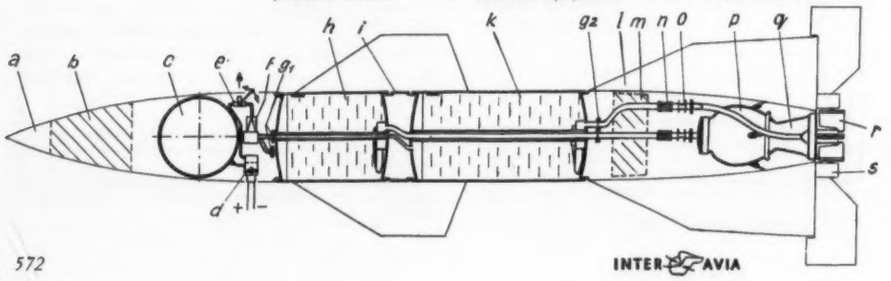
Fig. 12 : Take-off of an experimental rocket : A rail truck brought the rocket from the shed (1) to the launching point, (2) the firing crew took their places in the shelter (3) and fired the starting membrane.—The exhaust gases escape through an underground tunnel, (4) the rocket leaves the ground and will be remote-controlled by the radar set (5) (in the background).

The launching process, counting from the electrical ignition of the firing membrane to the take-off of the projectile, lasted 3 to 4 seconds. Accurate adjustment of all power plant parts was essential. Shutters O in front of the combustion chamber helped here. Some difficulties were experienced with the pressure reducer, which had to build up an adequate pressure in the tanks from the start and had to supply an increased quantity of propellants before the full combustion chamber counter-pressure was reached. If the design was bad in this respect there was a tendency for the missile to oscillate.

The projected duration of combustion of 45 seconds was not quite reached because it was very difficult to ensure that the tanks were fully emptied. In the early models the tanks had only simple outlets, which produced a loss of combustion time of up to 7 seconds. The reason for this was the formation of eddies occurring towards the end of the emptying (fig. 13a), which caused the pressure gas (nitrogen) in the tank to pass too soon into the combustion chamber. A further loss in combustion time was due to the fact that the projected exhaust velocity (1870 m/sec.) was not obtained. The combination finally used (and design value achieved) gave only 1780 m/sec. under test. The fuel consumption (for 8-tonnes thrust) had, therefore, correspondingly to be increased.

Fig. 11 : Structural diagram of the " Wasserfall " A/A missile.

a	fuse	g_1	bursting membrane	n	elastic hoses
b	explosive warhead	g_2	bursting membrane	o	shutter
c	high pressure ball (nitrogen)	h	combustible tank	p	combustion chamber
		i	body joint	q	Laval duct
d	firing membrane	k	acid tank	r	jet vanes
e	three-way cock	l	tail with control surfaces	s	power units for movable control surfaces
f	pressure reducer	m	electrical equipment		



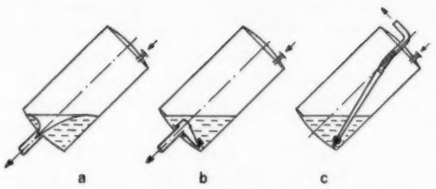


Fig. 13 : The formation of a whirlpool (a) prevented the complete emptying of the tank and resulted in loss of combustion time. This was remedied first by a swivel arm (b) and later by a flexible tube (c) (from suggestions of Dipl. Ing. Mebus ; Ed.)

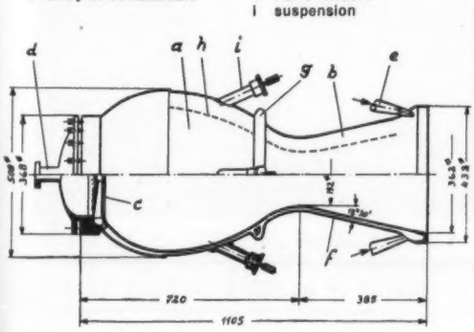
So as to reduce the emptying difficulties and consequent losses of combustion time a swivel-arm was built into each of the tanks.—This adapted itself to the attitude of the projectile so that the openings were always at the lowest point (fig. 13b). Even this arrangement was not entirely satisfactory and it was intended to replace it with a flexible tube (fig. 13c). The emptying of the tanks was rendered particularly difficult because the " Wasserfall " could take up any position in space and the surface level of the propellants was greatly influenced by the acceleration forces during pursuit flight. Unlike the V2 the end of the combustion (power cut-off) was not important since the " Wasserfall " was to be remote-controlled up to the moment it reached its target.

The high pressure chamber of spherical shape used for storing the pressure gas (nitrogen) was designed for an operating pressure of 250 kg/cm² and had the lowest acceptable safety margin. Steel had been found suitable for its construction. Experimental models of light metal—with steel " bandages" as in the V1—were also used, but only in tests. Since the share of the nitrogen container in the total weight of the missile was considerable it was planned to substitute other systems. In particular experiments were being made with an arrangement whereby a fire gas was produced by burning self-igniting propellants, cooled by water injection and used to set the tanks under pressure.

Fig. 14 shows the combustion chamber with the injection nozzle and Laval duct. Originally an oven pressure of 16 kg/cm² was provided for. Later however the combustion chamber was found to be too small in volume, which resulted in efficiency losses. The oven pressure therefore had to be raised to 20 kg/cm². No further increase in pressure, such as would have improved the exhaust velocity, could be made because the propellant tanks were not strong enough for adequate augmentation of their internal pressure. The combustion chamber had a cooling jacket. In contrast to the V2 the oxidizer (nitric acid) acted as coolant.

Fig. 14 : The " Wasserfall's " 8-tonne oven.

a combustion chamber
b Laval duct
c injection nozzle
d entry of combustible
e entry of acid
f cooling jacket
g expansion rail
h flame holders
i suspension



The development of the injection nozzle was rather costly. It was found that its quality largely determined the efficiency of the projectile. The material used at first was an ordinary carbon steel, and later a light metal alloy. To avoid the necessity of machining, the series version was cast in moulds (with sufficient accuracy). Its construction can be seen in fig. 15. While the combustible passed direct into the combustion chamber through axial tunnels *A* and slots *B*, the acid flowed out of the cooling jacket into radial channels *C* and then passed through tunnels *D* in steel *supports E* into the combustion chamber. A particularly important factor in good ignition and smooth combustion was the distribution of the various injection sections. For example a specified zone had to ensure the spontaneous ignition during the starting of the engine ; the thermal stresses on the combustion chamber had to be as evenly distributed as possible ; a veil of combustible was required in the boundary area of the oven. In view of these requirements and the limited nature of earlier experience at Peenemünde the injection nozzle could be worked out only empirically. After a large number of tests on the test bench the solution illustrated was arrived at. Zone *Z* represents an " impulsion ring " from which ignition takes place, with the aid of four orifices for the acid which spray at an angle towards the combustible-slot in their centre (fig. 16). Better solutions had been planned but had not reached the production stage. For example, it was planned to make the injection device of steel again and to weld it direct into the head of the combustion chamber.

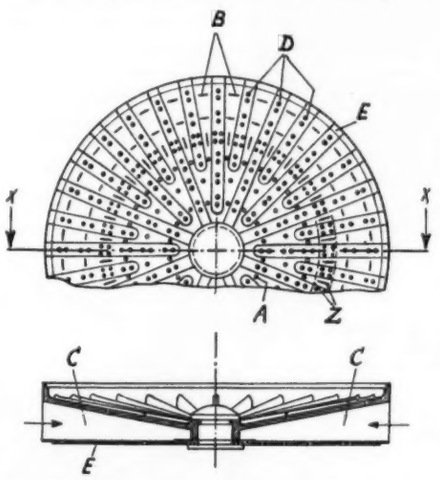


Fig. 15 : Side-view and section of injection nozzles.

A combustible tunnels
B combustible slots
C acid channels
D acid tunnels
E inserted steel strips
Z impulsion ring

The four jet vanes in the gas stream of the rocket had the same task as in the V2.

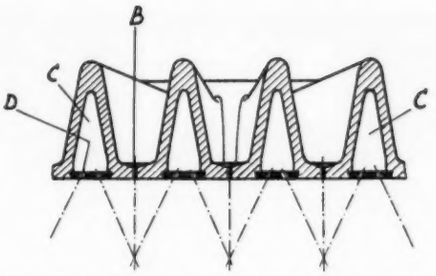


Fig. 16 : Section of the impulsion ring of the injection nozzle :

B combustible slot
C acid channels
D acid tunnels

They served to stabilise and steer the missile until it had sufficient speed to be controllable by the air forces. The material used was graphite. Since however, even with the best possible design, a considerable increase in hinge moments due to asymmetrical burning-off of the vanes was unavoidable, the jet vanes were detached *after 10 seconds* in the last experiments (fig. 17), and subsequent steering was made entirely by means of the control surfaces. A further advantage of this arrangement was that the effect of the jet vanes on the jet stream was eliminated, which improved the effective exhaust velocity by about 5%.

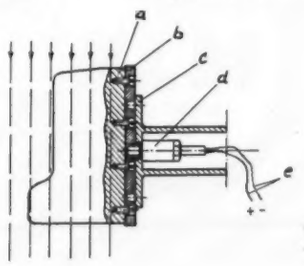
The requirement that it should be possible to store the A/A missiles for a long time fully fuelled and ready to launch gave rise to difficulties in the planned large-scale production. In particular the acid tank was susceptible to corrosion. Neither pure aluminium nor chrome alloys could be used on account of the shortage of raw materials. Tanks that were enamelled or lined with acid-proof plastics did not give satisfactory results. On the other hand tanks made of ordinary steel sheet, after special surface treatment, were found suitable. However, the anti-corrosion capacity necessary for the mass production planned was not available. All the experimental projectiles were therefore fired off without anti-corrosion treatment and could only be kept for a few days once they had been filled with nitric acid.

Tests and plans for operational use.

The first combustion tests were made as early as the end of 1942 with an experimental oven for 4.2-tonnes thrust on what was then the only test bench available to the " Wasserfall " programme. After completion of the first 8-tonne oven, combustion tests were begun with it on a test bench built in 1943. Moreover the test bench for 4.2-tonne ovens

Fig. 17 : Arrangement of the detachable jet vanes.

a jet vane
b steel strip
c vane axle
d cartridge with powder charge
e ignition cable



was completely rebuilt to suit the new conditions (fig. 18). The first projectile was fired without control in February 1944. For safety reasons, it was launched from one of the islands near the Peenemünde establishment. The missile went off entirely satisfactorily, but showed a tendency to oscillatory motion when approaching the speed of sound. It left its trajectory and dived into the sea not far from the launching point.

After some modifications to the missile and another 10 ascents, the launching base could be transferred to the Peenemünde proofing grounds. With a new test bench completed during the autumn of 1944, it was possible to carry out combustion tests on the complete missile on the ground. In addition a floating test bench for oven and missile testing was built to escape the constant danger of air raids. It consisted of two ships' hulls between which the test framework had been constructed, and could be moved about from one position to another under the power of four automobile engines.

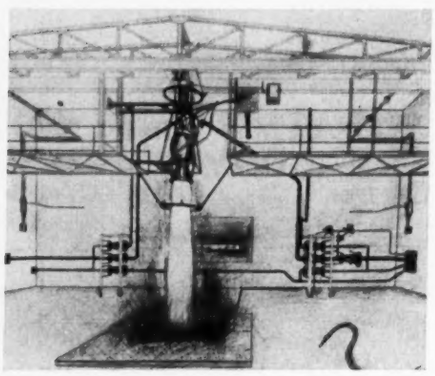


Fig. 18 : The " Wasserfall's " 8-tonne oven during a combustion test. Behind the observation slot is the test engineer's shelter from which all the valves, etc. are operated ; tanks and measuring equipment for the propellants are also protected from damage (drawing by the author).

Some 35 rockets were launched up to the beginning of 1945. Most of them were remotely controlled by means of a stick arrangement added to the beam method. Some missiles carried transmitters to send important experimental data to the ground station during their flight. In February, 1945, work had to be discontinued owing to the dismantling of the Peenemünde works and the transfer of the equipment to central Germany.

Production of 5000 projectiles a month for operational use was planned. This figure was calculated on the basis of the effective range and estimated accuracy of the missile, the size of the area to be protected and the expected frequency of enemy incursions. It would probably not have been possible to protect the whole of the metropolitan area by " Wasserfall," but only a relatively narrow strip. Another plan called for the protection of military or industrial key points only.

The above describes the development of " Wasserfall " only in broad outline. Many of the results of painstaking detailed work have not been mentioned. That this A/A missile with what was then the largest acid-propellant rocket engine was not an ideal solution was recognised already during the war. Even if its development had reached a suitable stage, an output of some 5000 missiles a month would certainly have been impossible in view of industrial conditions at the time.

For this reason a new type of missile was demanded. It was to fill the same requirements as the " Wasserfall," but to cost only one third as much to construct. And a new A/A missile of this kind (approx. 50 cm. calibre and 4-tonnes thrust) was really in the design stage at the end of the war. In all probability present-day development too, should aim at very much smaller missiles for anti-aircraft defence purposes. This will not alter greatly the principle of guided supersonic projectiles of which the " Wasserfall " was a typical example.

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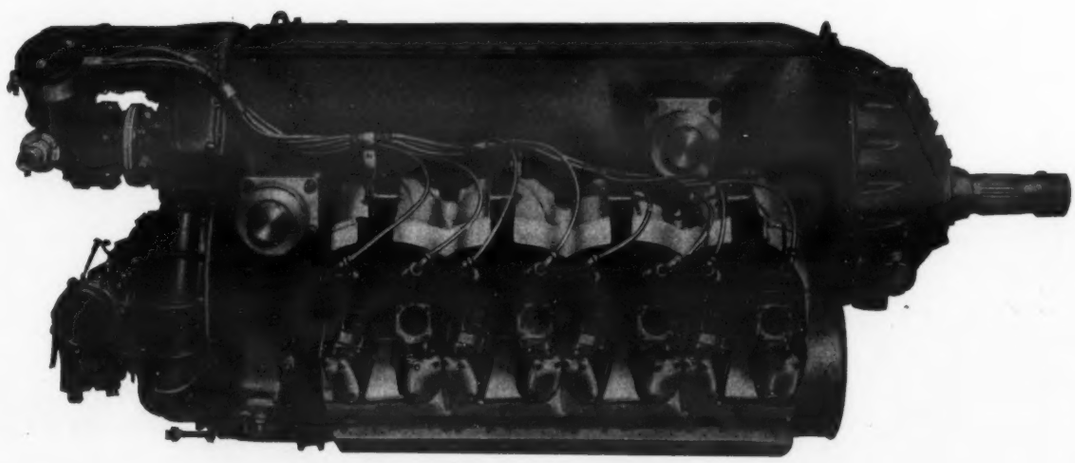

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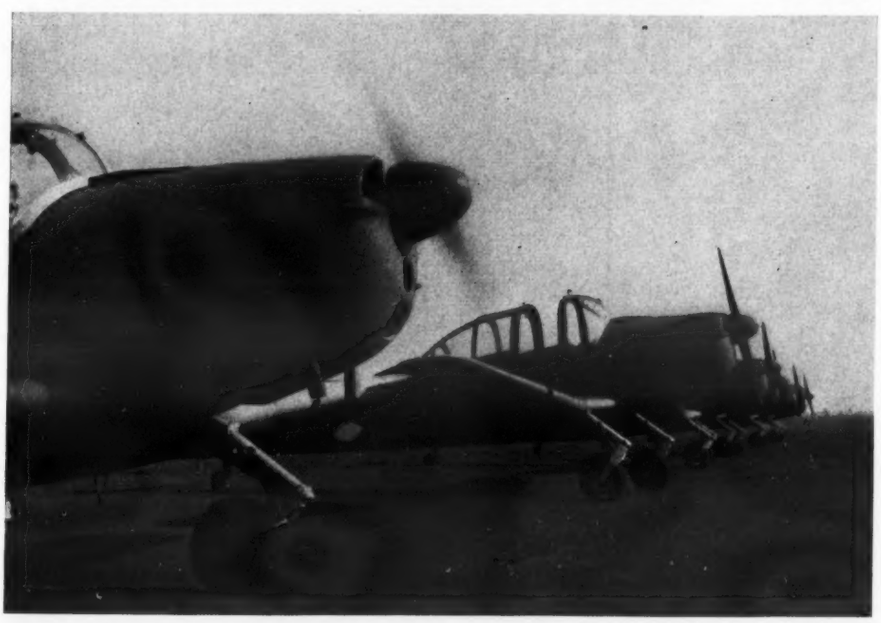

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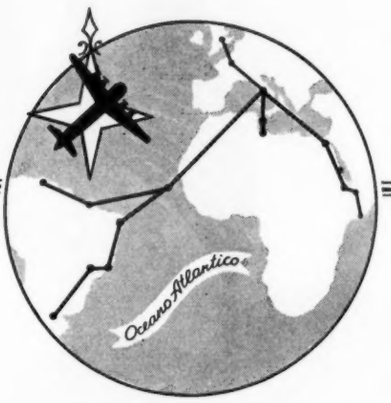

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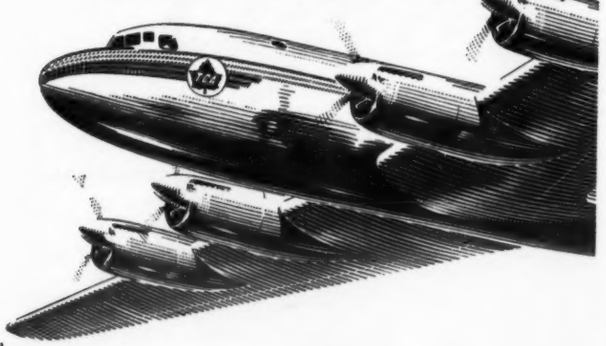

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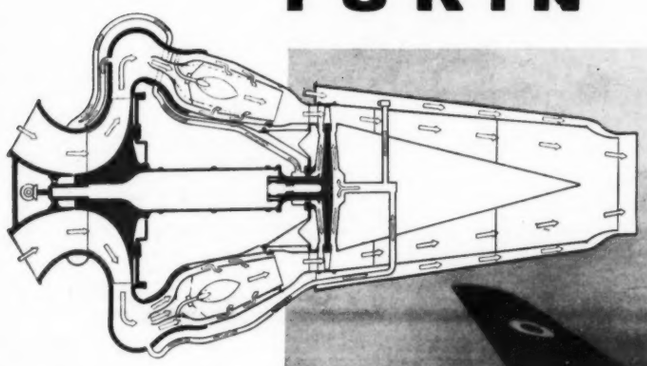
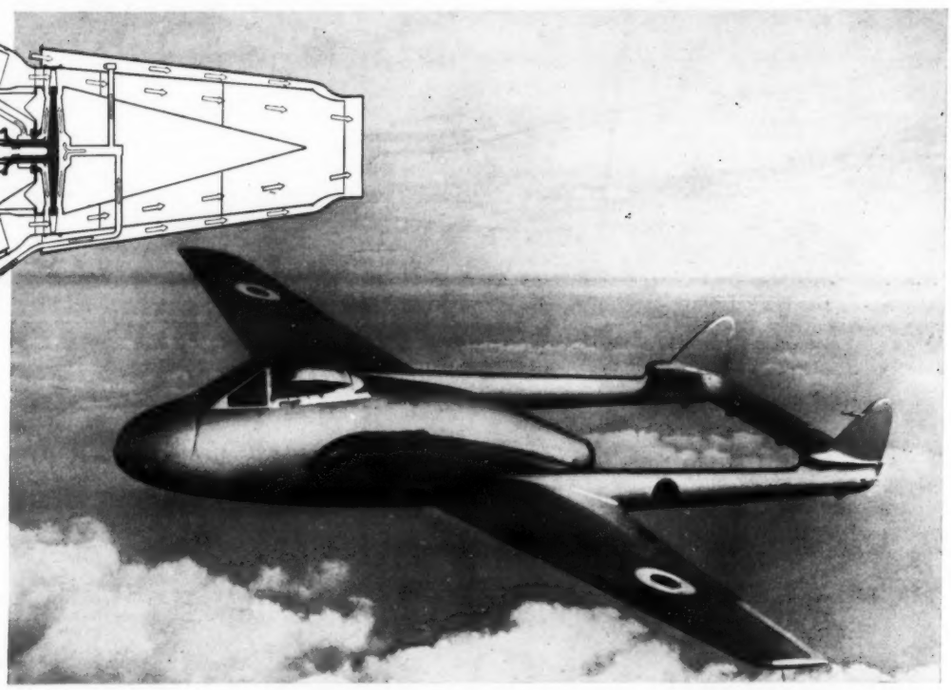
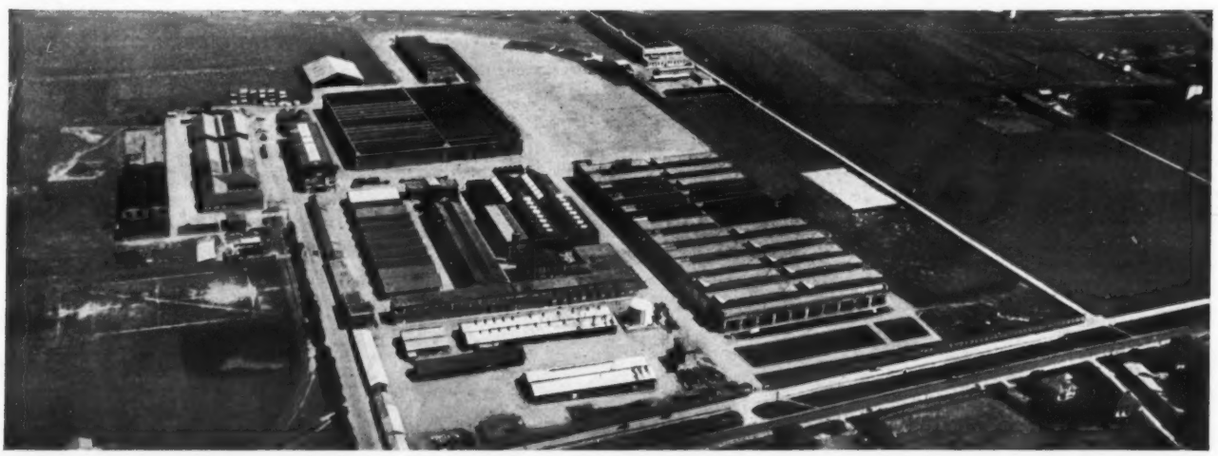


"Ghost" jet engine (De Havilland licence)



"Vampire" fighter (De Havilland licence)

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